A

MANUAL OF BOTANY

VOL. II.

CLASSIFICATION AND PHYSIOLOGY

A

MANUAL OF BOTANY

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CONTENTS

BOOK III.

SYSTEMATIC BOTANY, OR THE CLASSIFICATION OF PLANTS.

CHAPTER I.

CHAPTER II.

CHAPTER III.

CHAPTER IV.

CHAPTER V.

CHAPTER VI.

BOOK IV.

PHYSIOLOGY OF PLANTS.

CHAPTER I.

CHAPTER II.

CHAPTER III.

CHAPTER IV.

CHAPTER V.

CHAPTER VI.

CHAPTER VII.

CHAPTER VIII.

CHAPTER IX.

CHAPTER X.

CHAPTER XI.

CHAPTER XII.

CHAPTER XIII.

CHAPTER XIV.

CHAPTER XV.

CHAPTER XVI.

CHAPTER XVII.

CHAPTER XVIII.

MANUAL OF BOTANY.

BOOK III.

SYSTEMATIC BOTANY, OR THE CLASSIFICATION OF PLANTS.

CHAPTER I.

GENERAL PRINCIPLES OF CLASSIFICATION.

SECTION 1.—SPECIES, GENERA, ORDERS, AND CLASSES.

OUR attention has been hitherto directed to the examination of the structure and shapes of the various organs and parts of plants. In doing so, we cannot but have noticed the almost infinite varieties of forms which have thus been presented to us, and also at the same time observed that, notwithstanding such variations, there are some striking resemblances in the structure of the members of certain plants, by which a close relationship is thus clearly indicated between them. It is the object of Systematic Botany to take notice of such relationships, and thus to bring plants together which are allied in their forms and structure, and to separate those that are unlike; and in this way to take a comprehensive view of the whole Vegetable Kingdom. In its extended sense, Systematic Botany has for its object the naming, describing, and arranging of plants in such a manner that we may readily ascertain their names, and at the same time get an insight into their affinities and general properties.

At the present time there are at least 120,000 species of

plants known to exist on the earth. It is absolutely necessary therefore, for the purpose of study, or in order to obtain any satisfactory knowledge of such a vast number of plants, that we should arrange them according to some definite and fixed rules; but before we proceed to describe the systems that have been devised at various times for their arrangement, it will be necessary to define the principal terms which are in common use in such systems.

1. Species.—By the term species we understand a collection of individuals which resemble each other more nearly than they resemble any other plants, so that we may infer that they have all been derived originally from one common stock. Thus, if we walk into a field of Beans, Peas. or Clover, we observe thousands of individuals, which, although differing to a certain extent in size, and in some other unimportant characters, we at once associate together under a common name. In like manner we commonly observe around us, in the gardens and fields, similar collections of individuals. Such collections of plants, thus seen to resemble one another in all their important parts, constitute our first idea of a species; and that idea is at once confirmed if, on propagating them, we obtain other plants exactly resembling the parents. Species are, however, under special conditions, liable to variations, and we have then formed what are termed *varieties* and *races*.

a. *Varieties or Sub-species.*—It has just been observed that if a species be propagated it will reproduce its parent, or, in other words, produce a plant resembling its parent in all its important parts. But this will only happen when the new individual has been exposed to the same influences of soil, heat, light, moisture, and other conditions, as its parent; and hence we find that variations in such particulars will lead to certain peculiarities in form, colour, size, and other minor characters, in the young plants. In this manner we have produced what are termed *varieties.* In some cases such variations are merely transient, and the individuals presenting such peculiarities will in time return to their original specific type, or perish altogether; while in other instances they are permanent and continue throughout the life of the individual, the whole plant being, as it were, impregnated with the particular variations thus impressed upon it, and hence such variations may be perpetuated by the gardener in the operations of Budding, Grafting, &c., as is the case with many of our fruit trees and flowers. But even these varieties are not perma-

nent; for the successive generations which will be produced will have a tendency to revert to the original species from which such varieties have been obtained, so that the nature of the plant raised will depend upon the character of the soil in which it is placed, and the other external conditions to which it is exposed. Thus, if we sow the seeds of a number of different varieties of Apples, the fruit subsequently produced by the new generation of Apple trees will, instead of resembling that of their parents, have a tendency to revert to that of the common Crab, from which species all such varieties have been originally derived. Hence a variety differs essentially from a species in the fact that it cannot be propagated without tending to revert to the type from which it sprang.

b. *Races.*—Besides the varieties just alluded to, there are others, which are called *permanent varieties* or *races*, because their peculiarities can be transmitted by seed. Familiar examples of such races are afforded by our Cereal grains, as Wheat, Oats, and Barley; and also by our culinary vegetables, as Peas, Lettuces, Radishes, Cabbages, Cauliflowers, and Broccoli. How such races of plants have originated, it is impossible to say with any certainty. At the outset they probably arose in an accidental manner, for it is found that plants under cultivation are liable to produce certain variations or abnormal deviations from their specific type, or to *sport*, as it is termed. By further cultivation under the care of the gardener, such variations are after a time rendered permanent, and can be propagated by seed. These so-called permanent varieties, however, if left to themselves, or if sown in poor soil, will soon lose their peculiarities, and either perish, or return to their original specific type; it will be seen, therefore, that races present well-marked characters by which they are distinguished from true species. Hence, although our cereal grains and culinary vegetables have become permanent varieties by ages of cultivation and by the skill of the cultivator, they can only be made to continue in that state by a resort to the same means, for if left to themselves they would, as just observed, either perish or revert to their original specific type; and hence we see also how important is the assistance of the agriculturist and gardener in perpetuating and improving such variations.

Another cause which leads to constant variations from the specific type is *hybridisation.* The varieties thus formed, which are called *hybrids* and *cross-breeds*, are, however, rarely constant for long—although, in some instances, such is the case for a few

generations—but they gradually revert to one or the other parent stock.

We have now seen that species, under certain circumstances, are liable to variations, but that all such varieties have a tendency to revert to their original specific type. Hence, from a practical point of view, species must be considered as permanent productions of Nature, which are capable of varying within certain limits, but in no cases capable of being altered so as to assume the characters of another species. There is not the slightest foundation for the theory, which has been advocated by some naturalists, of a transmutation of species. All such statements, therefore, that have been made, of the conversion of Oats into Rye, or of any species whatever into another, are entirely without foundation, and have arisen from imperfect observation.

In practice it is important that we should distinguish varieties from true species, for nothing is so calculated to lead to confusion in Descriptive Botany as the raising of mere varieties to the condition of species. No individuals should be considered as constituting a species unless they exhibit important and permanent distinctive characters in a wild state. Great uncertainty still prevails in our systematic works as to what is a species and what is a variety; and hence we find different authors, who have written on British and other plants, estimate the number of species contained in such genera as *Rosa*, *Rubus*, *Saxifraga*, *Hieracium*, *Salix*, *Smilax*, and others, very differently.

2. GENERA.—The most superficial observer of plants will have noticed that certain species are more nearly allied to each other than to other species. Thus, the different kinds of Roses, Brambles, Heaths, Willows, may be cited as familiar examples such assemblages of species; for, although the plants comprehended under these names present certain well-marked distinctive characters, yet there are at the same time also striking resemblances between them. Such assemblages of species are called *genera*. A *genus*, therefore, is a collection of species which resemble each other in general structure and appearance more than they resemble any other species. Thus, the various kinds of Brambles constitute one genus, the Roses another, the Willows, Heaths, Clovers, and Oaks form also, in like manner, as many different genera. The characters of a genus are taken *exclusively* from the organs of reproduction, while those of a species are derived *generally* from all parts of the plant; hence

a genus is defined as a collection of species which resemble each other in the structure and general characters of their organs of reproduction. It is not necessary, however, that a genus should contain a number of species, for, if a single species presents peculiarities of a marked kind, it may of itself constitute a genus.

It frequently happens that two or more species of a genus have a more striking resemblance to each other in certain important characters than to other species of the same genus, in which case they are grouped together into what is termed a *sub-genus*, and further subdivisions of more nearly allied species, such as *sections*, *sub-sections*, &c., may be made.

3. Orders or Natural Orders.—If we regard collections of genera from the same point of view as we have just done those of species,—that is, as to their close resemblances,—we shall find that some of them also resemble each other more than they do other genera. Thus, Mustards, Turnips, Radishes, and Cabbages have a strong common resemblance, while they are unlike Strawberries and Brambles, even less like Hazels, Oaks, and Beeches, and still more unlike Larches, Pines, Firs, and Cedars. Proceeding in this way throughout the Vegetable Kingdom, we collect together allied genera, and form them into groups of a higher order called *Orders* or *Natural Orders*; hence, while genera are collections of related species, orders are collections of allied genera. Thus, Turnips, Radishes, and Cabbages, all belong to different genera, but they agree in their general structure, and are hence included in the order *Cruciferæ*; while Strawberries, Brambles, Roses, Apples, and Plums, constitute different genera, but, from the general resemblance they bear to each other in their structure, they are placed in one order, called *Rosaceæ*. Again: Oaks, Beeches, and Hazels belong to different genera, but to one order; also the Pines and Cedars are different genera, but as the fruit of them all is a *cone*, they are grouped together in one order, which is termed the *Coniferæ*.

We find also that certain genera of an order, like certain species of a genus, have a more striking resemblance to each other than to other genera of the same order; hence such are grouped together into what are called *Sub-orders*. Thus the Chicory, Dandelion, Sow-thistle, Lettuce, Thistle, Burdock, and Chamomile, all belong to the same order, but there is a greater resemblance in the Chicory, Dandelion, Sow-thistle, and Lettuce to each other than to the Thistle and Burdock. Hence, while all

the above genera belong to the order *Compositæ*, they are at the same time placed in two different sub-orders. Thus, one sub-order, called the *Liguliflorœ*, includes the Chicory, Dandelion, Sow-thistle, and Lettuce; and another sub-order, the *Tubuliflorœ*, that of the Thistle, Burdock, and Chamomile. In like manner, while we find the Plum, Strawberry, Raspberry, Rose, and Apple, all belonging to the same order *Rosaceæ*, some of them have more resemblance to each other than to others. Thus, the Plum has a drupaceous fruit, and is therefore placed in a distinct sub-order, which is called *Drupaceæ*; the Strawberry, Raspberry, and Rose are much more like each other than they are like the Plum or Apple, and they are put in a sub-order called *Rosæ*; while the Apple, from the character of its fruit, is placed in a sub-order termed *Pomeæ*.

It is also found convenient to subdivide sub-orders into *Tribes*, *Sub-tribes*, &c., by collecting together into groups certain very nearly allied genera, but it is not necessary for us to illustrate such divisions further, as the principles upon which they depend have been now sufficiently treated of.

4. Classes.—By a class we understand a group of orders possessing some very important structural characters in common. Thus we have the classes Monocotyledones and Dicotyledones, which possess certain distinctive characters in their respective embryos, &c.

The Classes are also divided into *Sub-classes*, *Series*, *Cohorts* or *Alliances*, and other divisions, in the same manner as the orders, genera, and species are subdivided; but as the names of such divisions vary in different systems, and are all more or less artificial, it is not necessary for us, in this place, to dwell upon them further. The classes themselves, in different systems, are also generally arranged in more comprehensive groups, which have been variously named *Sub-kingdoms*, *Groups*, *Divisions*, *Regions*, *Sub-divisions*, &c. But as these are also of different extent and variously defined by botanists, we must refer to the several systems for particulars respecting them.

The following table will include all the more important groups we have alluded to; those in more general use being indicated by capitals.

1. SUB-KINGDOMS OR DIVISIONS.
    Sub-divisions.
  2. CLASSES.
      Sub-classes.
        Series.
          Cohorts or Alliances.
    3. ORDERS.
        Sub-orders.
          Tribes.
            Sub-tribes.
      4. GENERA.
          Sub-genera.
            Sections.
        5. SPECIES.
            Varieties.
              Races.

SECTION 2.—CHARACTERS, NOMENCLATURE, ABBREVIATIONS, AND SYMBOLS.

DESCRIPTIVE BOTANY is the art of describing plants in technical language, so that they may be readily recognised when met with by those to whom they were previously unknown, who possess a knowledge of the technical names of the different parts and organs of plants and of their various modifications. This subject is too extensive to be treated of here; reference must be made to special treatises for this purpose; but it is necessary for us to refer briefly to the Characters, Nomenclature, Abbreviations, and Symbols of Plants.

1. CHARACTERS.—By the term 'character,' we mean a list of all the points by which any particular *variety*, *species*, *sub-genus*, *genus*, *sub-tribe*, *tribe*, *sub-order*, *order*, *sub-class*, or *class*, &c., is distinguished from another. We have also two kinds of characters, which are called respectively *essential* and *natural*. By an essential character, we understand an enumeration of those points only, by which any division of plants may be distinguished from others of the same nature; such may be also called *diagnostic* characters. A *natural character*, on the other hand, is a complete description of a given species, genus, order, class, &c., including an account of every organ from the root upwards, through the stem, leaves, flowers, fruit, and seed. Such characters are necessarily of great length, and are not required for general diagnosis, although of great value when a complete

history of a plant or group is required. Those characters, again, which refer to a species are called *specific*, and are taken generally from all the organs and parts of the plant, and relate chiefly to their *form*, *shape*, *surface*, *division*, *colour*, *dimension*, and *duration*; or, in other words, to characters of a superficial nature, and without reference to their internal structure. The characters of a genus are called *generic*, and are taken from the organs of reproduction. The characters of an order are termed *ordinal*, and are derived from the general structure of the plants in such groups, more especially of the organs of reproduction; while the characters of a class, &c., as already mentioned, are derived from certain important structural peculiarities which the plants of such divisions exhibit.

2. Nomenclature.—It is the object of nomenclature to lay down rules for naming the various kinds of plants and the different groups into which they are arranged in our systems of classification; in the same manner as it is the object of terminology to find names for the different organs of plants, and the modifications which those organs present.

a. *Species*.—The names of the species are variously derived. Thus the species of the genus *Viola*, as shown by Gray in the following paragraphs, exhibit the origin of many such names. 'Specific names sometimes distinguish the country which a plant inhabits: for example, *Viola canadensis*, the Canadian Violet; or the station where it naturally grows, as *Viola palustris*, which is found in swamps, and *Viola arvensis*, in fields; or they express some obvious character of the species, as *Viola rostrata*, where the corolla bears a remarkably long spur, *Viola tricolor*, which has tri-coloured flowers, *Viola rotundifolia*, with rounded leaves, *Viola lanceolata*, with lanceolate leaves, *Viola pedata*, with pedately-parted leaves, *Viola primulæfolia*, where the leaves are compared to those of a Primrose, *Viola asarifolia*, where they are likened to those of *Asarum*, *Viola pubescens*, which is hairy throughout, &c. Frequently the species bears the name of its discoverer or describer, as *Viola Muhlenbergii*, *Viola Nuttallii*, &c.

Specific names are written after the generic, as indicated above in the different species of the genus *Viola*, and these together constitute the proper appellation of a plant, in the same way as the surnames and christian names designate the members of a family. The specific names should also in all cases be adjectives or substantives used adjectively; in the former case they should agree in gender and case with the name

of the genus. Thus, when a species is named after its discoverer or describer, it is usually placed in the genitive case, as *Viola Muhlenbergii* and *V. Nuttallii*; but when such names are merely given in honour of botanists who have had nothing to do with their discovery or description, the specific names are generally put in the adjective form, as *Carex Hookeriana*, *Veronica Lindleyana*: such a rule is, however, frequently departed from. Sometimes the specific name is a noun, in which case it does not necessarily agree with the genus in gender; such specific names are often old generic ones, as *Dictamnus Fraxinella*, *Rhus Cotinus*, *Lythrum Salicaria*, *Rhus Coriaria*, *Dianthus Armeria*, *Rhamnus Frangula*. In such cases the specific name should begin with a capital letter; a similar rule should also be adopted when it is derived from a person; but in all other instances it is better that the specific name should begin with a small letter. The specific name was called by Linnæus the *trivial* name; thus, in the particular kind of Violet called *Viola palustris*, *Viola* is the generic, and *palustris* the specific or trivial name.

b. *Genera.*—The names of the genera are substantives, in accordance with the rule laid down by Linnæus as follows:—Every species shall have a particular name, compounded of a substantive and an adjective, whereof the former indicates the genus, and the latter the species. This has already been referred to under the head of Species. The names of the genera are derived in various ways: thus, either from the name of some eminent botanist, as Linnæa after Linnæus, Smithia after Smith, Hookeria after Hooker, Jussiæ after Jussieu, Tournefortia after Tournefort, Lindleyana after Lindley; or from some peculiarity of structure or habit of the plants comprised in them, and from various other circumstances. Thus, *Crassula* is derived from the genus comprising plants with succulent or thickened leaves; *Sagittaria*, from its arrow-shaped leaves; *Arenaria*, from growing in sandy places; *Lithospermum*, from its fruits (which were formerly regarded as seeds) having a stony hardness; *Campanula*, from its corolla being in the form of a bell; *Lactuca*, from its milky juice; and so on. Others, again, have derived their generic names from supposed medicinal properties, such as *Scrophularia*, from its former use in scrofula; *Pulmonaria*, from its employment in pulmonary disease, &c.

c. *Orders.*—The names of the orders in the Artificial System of Linnæus are chiefly derived from the various characters of the gynœcium and fruit. Those of Natural Systems are

usually taken from some well-known genus which is included in any particular order, and which may be regarded as the type of that order. Thus, the genus *Ranunculus* gives the name *Ranunculaceæ* to the order to which it belongs; the genera *Papaver*, *Malva*, *Hypericum*, *Geranium*, *Rosa*, *Lilium*, *Orchis*, and *Iris*, in like manner, give names respectively to the orders *Papaveraceæ*, *Malvaceæ*, *Hypericaceæ*, *Geraniaceæ*, *Rosaceæ*, *Liliaceæ*, *Orchidaceæ*, and *Iridaceæ*. At other times the names of the orders are derived from some characteristic feature which the plants included in them present. Thus, the order *Cruciferæ* is so named because its plants have cruciate corollas; the order *Leguminosæ* because the fruit of its members is, with few exceptions, a legume; the *Umbelliferæ* are umbel-bearing plants; the *Labiatæ* have a labiate corolla; the *Coniferæ* are cone-bearing plants; and so on.

d. *Classes.*—The names of the classes are derived from some important and permanent characters which the plants comprised in them possess, relating either to their structure or mode of development. Such names vary, however, according to the views of different systematic botanists. Examples of those which have been more commonly used in this country are *Monocotyledones* and *Dicotyledones*—terms which are derived from the structure and characters of the reproductive bodies in those classes respectively. The above names are used especially in Natural Systems of Classification; while the names of classes in the Artificial System of Linnæus are derived chiefly from the number and other characters presented by the andrœcium.

e. *Sub-kingdoms*, *Divisions*, *&c.*—The names of these are generally derived from some well-marked peculiarity of typical forms; thus we have the *Bryophyta* or Moss-like plants, the *Pteridophyta* or Fern like plants, the *Spermaphyta* or plants which produce seeds, sometimes called *Phanerogamia* because their sporophylls are usually collected into evident flowers. The other sub-divisions are variously named according to the views of different botanists.

3. Abbreviations and Symbols.—It is usual in botanical works to use certain abbreviations and symbols. A few of the more important need alone be mentioned here.

The names of authors, when of more than one syllable, are commonly abbreviated by writing the first letter or syllable, &c., as follows:—

L. or *Linn.* means Linnæus; *Juss.* is the abbreviation for

Jussieu; *DC.* or *De Cand.* for De Candolle; *Br.* for Brown; *Lindl.* for Lindley; *Rich.* for Richard; *Willd.* for Willdenow; *Hook.* for Hooker; *With.* for Withering; *Endl.* for Endlicher; *Bab.* for Babington; *Berk.* for Berkley, &c., &c.

It is common to put such abridged names after that of the genus or species which has been described by them respectively. Thus *Eriocaulon, L.* indicates that the genus *Eriocaulon* was first described by Linnæus; *Miltonia, Lindl.* is the genus *Miltonia* as defined by Lindley; *Nuphar pumila, DC.* is the species of *Nuphar* defined by De Candolle, &c., &c.

Other abbreviations in common use are *Rad.* for root; *Caul.* for stem; *Fl.* for flower; *Cal.* for calyx; *Cor.* for corolla; *Per.* for perianth; *Fr.* for fruit; *Ord.* for order; *Gen.* for genus; *Sp.* or *Spec.* for species; *Var.* for variety; *Hab.* for habitat; *Herb.* for herbarium, &c.

CHAPTER II.

SYSTEMS OF CLASSIFICATION.

We have already stated that Systematic Botany has for its object the naming, describing, and arranging of plants in such a manner that we may readily ascertain their names, and at the same time get an insight into their affinities and general properties. Every system that has been devised for the arrangement of plants does not, however, comprise all the above points; for, while some systems are of value simply for affording us a ready means of ascertaining their names, others not only do this, but at the same time give us a knowledge of their affinities and properties. Hence we divide the different systems of Classification under two heads; namely, Artificial and Natural—the former only necessarily enabling us to ascertain readily the name of a particular plant; while the latter, if perfect, should comprise all the points which come within the object of Systematic Botany. The great aim of the Botanist, therefore, should be the development of a true Natural System; but in past times, Artificial Systems, more particularly that of Linnæus, have been of great value. Linnæus himself never devised his system with any expectation or desire of its serving more than a temporary purpose, or as an introduction to the Natural System, when the materials for its formation had been obtained.

In both artificial and natural systems, the lower divisions—namely, the genera and species—are the same, the difference between the systems consisting in the manner in which these divisions are grouped into orders, classes, and other higher groups. Thus in the Linnæan and other artificial systems, one, or, at most, a few characters are arbitrarily selected, and all the plants in the Vegetable Kingdom are distributed under classes and orders according to the correspondence or difference of the several genera in such respects, no regard being had to any other characters. The plants in the classes and orders of an

artificial system have, therefore, no necessary agreement with each other except in the characters selected for convenience as the types of those divisions respectively. Hence such a system may be compared to a dictionary, in which words are arranged, for convenience of reference, in an alphabetical order, adjacent words having no necessary agreement with each other, except in commencing with the same letter. In the Natural System, on the contrary, all the characters of the genera are taken into consideration, and those are grouped together into orders which correspond in the greatest number of important characters; and the orders are again united, upon the same principles, into groups of a higher order, namely, the classes and other divisions. While it must be evident, therefore, that all the knowledge we necessarily gain by an artificial system is the name of an unknown plant, on the other hand, by the natural system, we learn not only the name, but also its relations to the plants by which it is surrounded, and hence get a clue to its structure, properties, and history. Thus, supposing we find a plant, and wish to ascertain its name, if we turn to the Linnæan System and find that such a plant is the *Menyanthes trifoliata*, this name is the whole amount of the knowledge we have gained; but by turning to the Natural System instead, and finding that our plant belongs to the order *Gentianaceæ*, we ascertain at once from its affinities that it probably has the tonic and other properties which are possessed by the plants generally of that order, and, at the same time, we also learn that it accords in its structure with the same plants. It is quite true that all the orders, as at present constituted, are by no means so natural as that of the Gentianaceæ, but this arises from the present imperfection of our systems, and can only be remedied as our knowledge of plants extends; a system, devised as perfectly as possible one day, may be deficient the next, in consequence of new plants being discovered which may compel us to alter our views, for at present the floras of many regions of the globe are imperfectly known, and those of others almost entirely unknown. Sufficient, however, is now known of plants to enable us to establish certain great divisions according to a natural method, which after discoveries are not likely to affect to any important extent. The present imperfections of the Natural System are, therefore, comparatively unimportant, and will no doubt disappear as our knowledge of the flora of the globe becomes extended.

Having now described the general characters upon which

TABULAR VIEW OF THE LINNÆAN ARTIFICIAL SYSTEM.

					Classes.	Orders.
Stamens and pistil in the same flower	Stamens separate from the pistil.	Stamens not connected with each other.	Stamens of equal length, or at all events neither didynamous nor tetradynamous.	1 Stamen . . .	1. MONANDRIA.	1. MONOGYNIA, 1 free style or stigma.
				2 Stamens . . .	2. DIANDRIA.	2. DIGYNIA, 2 free styles or stigmas.
				3 ,, . . .	3. TRIANDRIA.	3. TRIGYNIA, 3 ,, ,,
				4 ,, . . .	4. TETRANDRIA.	4. TETRAGYNIA, 4 ,, ,,
				5 ,, . .	5. PENTANDRIA.	5. PENTAGYNIA, 5 ,, ,,
				6 ,, .	6. HEXANDRIA.	6. HEXAGYNIA, 6 ,, ,,
				7 ,, . . .	7. HEPTANDRIA.	7. HEPTAGYNIA, 7 ,, ,,
				8 ,, . . .	8. OCTANDRIA.	8 OCTAGYNIA, 8 ,, ,,
				9 ,, . . .	9. ENNEANDRIA.	9. ENNEAGYNIA, 9 ,, ,,
				10 ,, . . .	10. DECANDRIA.	10. DECAGYNIA, 10 ,, ,,
				12 to 19,, . . .	11. DODECANDRIA.	11. DODECAGYNIA, 12 to 19 ,, ,,
				20 or more, perigynous	12. ICOSANDRIA.	12. POLYGYNIA, 20 or more ,, ,,
				20 or more, hypogynous	13. POLYANDRIA.	
			Of unequal length.	Two long and two short stamens.	14. DIDYNAMIA.	1. GYMNOSPERMIA, Fruit achænia, with one seed. 2. ANGIOSPERMIA, Fruit capsular, with many seeds.
				Four long and two short stamens.	15. TETRADYNAMIA.	1. SILICULOSA, Fruit a Silicula. 2. SILIQUOSA, Fruit a Siliqua.
		Connected with each other.		By their filaments in one bundle.	16. MONADELPHIA.	1. TRIANDRIA, 3 stamens. 2. PENTANDRIA, 5 stamens. 3. HEXANDRIA, 6 stamens. &c., &c., as in first 13 classes.
				By their filaments in two bundles.	17. DIADELPHIA.	
				By their filaments in more than two bundles.	18. POLYADELPHIA.	
						1. POLYGAMIA ÆQUALIS. Florets in capitula, and all perfect. 2. POLYGAMIA SUPERFLUA. Florets in capitula; florets of the disk hermaphrodite, of the ray pistillate

Plants having — Stamens and pistil evident. — By their anthers.	19. SYNGENESIA.	3. POLYGAMIA FRUSTRANEA. Florets in capitula; those of the disk hermaphrodite, and those of the ray neuter.
			4. POLYGAMIA NECESSARIA. Florets in capitula; those of the disk staminate, and those of the ray pistillate.
			5. POLYGAMIA SEGREGATA. Florets in capitula; each with a separate involucre.
Stamen or stamens adherent to the pistil . . .		20. GYNANDRIA.	1. MONANDRIA, 1 stamen.
			2. DIANDRIA, 2 stamens; and so on according to the number of stamens, as in the first 13 classes.
In separate flowers	On the same plant .	21. MONŒCIA.	1. MONANDRIA, 1 stamen.
	On separate plants .	22. DIŒCIA.	2. DIANDRIA, 2 stamens.
			3. HEXANDRIA, 6 stamens.
			4 POLYANDRIA, numerous stamens; and so on, as in the first 13 classes.
			5. MONADELPHIA, stamens united into one bundle by their filaments.
			6. POLYADELPHIA, stamens united into several bundles by their filaments.
	Stamens and pistil separate in some flowers, and united in others, either on the same or on two or three different plants.	23. POLYGAMIA.	1. MONŒCIA, with staminate, pistillate, and hermaphrodite flowers on the same plant.
			2. DIŒCIA. With hermaphrodite flowers on one plant, and staminate and pistillate flowers on another plant of the same species.
			3. TRIŒCIA, where one plant bears hermaphrodite, another staminate, and a third pistillate flowers.
Plants with organs of reproduction concealed or inconspicuous . . .		24. CRYPTOGAMIA.	FERNS, MOSSES, ALGÆ, FUNGI.

the artificial and natural systems depend, and the particular merits and disadvantages of the two kinds of system respectively, we proceed in the next place to describe the mode of construction of such systems, commencing with those of an artificial nature, which, however, will be only treated of very briefly.

Section 1.—Artificial Systems of Classification.

The first artificial system of any importance, of which we have any particular record, is that of Cæsalpinus, which was promulgated in 1583. Only 1520 plants were then known; and these were distributed into fifteen classes, the characters of which were chiefly derived from the fruit. The next systematic arrangement of an artificial character was that of Morison, about the year 1670. He divided plants into eighteen classes, which were constructed according to the nature of the flower and fruit, and the external appearance of the plants. The systems of Hermann and others were also constructed upon somewhat similar principles, while that of Camellus was framed from the characters presented by the valves of the pericarp, and their number. In the system of Rivinus, which was promulgated in the year 1690, plants were divided into eighteen classes; these were founded entirely upon the corolla—its regularity or irregularity, and the number of its parts being taken into consideration. The system of Christian Knaut was but a slight alteration of that of Rivinus. That of Tournefort, which was promulgated about the year 1695, was for a considerable time the favourite system of all botanists. About 8,000 species of plants were then known, which were distributed by Tournefort into twenty-two classes. He first arranged plants in two divisions, one of which comprised *herbs* and *under-shrubs*, and the other *trees* and *shrubs*: and each of these divisions was then divided into *classes*, which were chiefly characterised according to the form of the corolla. Many other systems were devised which were simply alterations of the foregoing, as that of Pontedera. Magnolius, however, framed a system entirely on the calyx; while Gleditsch attempted one in which the classes were founded on the position of the stamens. All the above systems were, without doubt, useful in their day, and paved the way for the more comprehensive one of Linnæus.

Linnæan System.—This celebrated system was first promulgated by Linnæus in his 'Systema Naturæ,' published in the year 1735; and although it was somewhat altered by subse-

quent botanists, the Linnæan System, in all its essential characters, was that devised by Linnæus himself; and although now superseded by natural systems, it will be advisable for us to give a general sketch of its principal characteristics.

The classes and orders in the Linnæan System are taken exclusively from the sporophylls; as these were considered to be the sexual organs of the plant, this artificial scheme is commonly termed the Sexual System.

The table (pp. 14 and 15) of the Classes and Orders of the Linnæan System will show at a glance their distinctive characteristics.

Section 2.—Natural Systems of Classification.

The first attempt at arranging plants according to their natural affinities was by our celebrated countryman, John Ray, in the year 1682; and imperfect as any scheme must necessarily have been at that day, when the number of plants known was very limited, still his arrangement was in its leading divisions correct, and has formed the foundation of all succeeding systems. He divided plants thus:—

1. Flowerless.
2. Flowering; these being again subdivided into
    a. Dicotyledons.
    b. Monocotyledons.

Ray still further grouped plants together into genera, which were equivalent to our natural orders, many of which indicated a true knowledge of natural affinities, and are substantially represented at the present day by such natural orders as the Fungi, Musci, Filices, Coniferæ, Labiatæ, Compositæ, Umbelliferæ, and Leguminosæ.

Tournefort, who flourished in France and was a contemporary of Ray, was the first botanist to define genera as we now accept them.

Next in order was the scheme propounded by the celebrated author of the most perfect artificial system ever devised for the arrangement of plants, namely, Linnæus, who, about the year 1751, drew up a sketch of the natural affinities of plants under the name of Fragments. Many of the divisions thus prepared by Linnæus are identical with natural orders as at present defined, among which we may mention Orchideæ, Gramina, Compositæ (nearly), Umbellatæ, Asperifoliæ, Papilionaceæ, Filices, Musci, and Fungi.

Jussieu's Natural System.—To Antoine Laurent de Jussieu, however, belongs the great merit of having first devised a comprehensive natural system. His method was first made known in the year 1789. It was founded upon the systems of Ray and Tournefort, to which he made some important additions, more especially in considering the position of the stamens with respect to the ovary. The following table, which requires no explanation, represents his arrangement.

			Class.
Acotyledons			1. Acotyledones.
Monocotyledons		Stamens hypogynous.	2. Monohypogynæ.
		Stamens perigynous.	3. Monoperigynæ.
		Stamens epigynous.	4. Monoepigynæ.
Dicotyledons.	Apetalæ	Stamens epigynous.	5. Epistamineæ.
		Stamens perigynous.	6. Peristamineæ.
		Stamens hypogynous.	7. Hypostamineæ.
	Monopetalæ	Corolla hypogynous.	8. Hypocorollæ.
		Corolla perigynous.	9. Pericorollæ.
		Corolla epigynous.	10. Epicorollæ Synantheræ (anthers coherent).
			11. Epicorollæ Corisantheræ (anthers distinct).
	Polypetalæ	Petals epigynous.	12. Epipetalæ.
		Petals hypogynous.	13. Hypopetalæ.
		Petals perigynous.	14. Peripetalæ.
	Diclines irregulares		15. Diclines.

Under these fifteen classes Jussieu arranged 100 natural orders or families. This was the first natural arrangement in which an attempt was made to assign characters to natural orders, but so admirably were these drawn up, that they have formed the basis of all succeeding systematists. Indeed, the limits of a great many of Jussieu's natural orders are identical with those of the present day.

De Candolle's Natural System.—The next system of note after that of Jussieu was that of Augustin Pyramus de Candolle, which was first promulgated in 1813. This system, modified, however, in some important particulars, is that which is most in use at the present day. In the first place, De Candolle divided plants into two great divisions or sub-kingdoms, called

Vasculares or Cotyledoneæ, and Cellulares or Acotyledoneæ, the characters of which he described as follows:—

Division 1. *Vasculares*, or *Cotyledoneæ*; that is, plants possessing both cellular (parenchymatous) tissue and vessels; and having an embryo with one or more cotyledons.

Division 2. *Cellulares*, or *Acotyledoneæ*; that is, plants composed of cellular (parenchymatous) tissue only; and whose embryo is not furnished with cotyledons.

The former division was again divided into two classes, called Exogenæ or Dicotyledoneæ, and Endogenæ or Monocotyledoneæ, the essential characters of which may be thus stated:—

Class 1. *Exogenæ*, or *Dicotyledoneæ*; that is, plants whose vessels are arranged in concentric layers, of which the youngest are the outermost and the softest; and having an embryo with opposite or whorled cotyledons.

Class 2. *Endogenæ*, or *Monocotyledoneæ*; that is, plants whose vessels are arranged in bundles, the youngest being in the middle of the trunk; and having an embryo with solitary or alternate cotyledons.

These classes were again divided into sub-classes or groups. Thus, under the Dicotyledoneæ were placed four groups, named Thalamifloræ, Calycifloræ, Corollifloræ, and Monochlamydeæ. Under the Monocotyledoneæ two groups were placed, called Phanerogamæ and Cryptogamæ. The latter group included what are now called the Vascular Cryptogams, or Pteridophyta. The Acotyledoneæ were also divided into two groups, called Foliosæ and Aphyllæ.

The following is a tabular view of De Candolle's system.

Sub-Kingdom 1.—VASCULARES, OR COTYLEDONEÆ.

Class 1. *Exogenæ*, or *Dicotyledoneæ*.

Sub-Class 1. *Thalamifloræ*	Petals distinct, inserted with the stamens on the thalamus.
2. *Calycifloræ*	Petals distinct or more or less united, and inserted on the calyx.
3. *Corollifloræ*	Petals united, and inserted on the thalamus.
4. *Monochlamydeæ*	Having only a single circle or floral envelopes, or none.

Class 2. *Endogenæ*, or *Monocotyledonæ*.

Sub-Class 1. *Phanerogamæ*	Fructification visible, regular.
2. *Cryptogamæ*	Fructification hidden, unknown, or irregular.

Sub-Kingdom 2. Cellulares, or Acotyledoneæ.

Sub-Class 1. *Foliosæ*	Having leaf-like expansions, and known sexes.
2. *Aphyllæ*	Having no leaf-like expansions, and no known sexes.

Under these sub-classes De Candolle arranged 161 Natural Orders. The enumeration of these is unnecessary in an elementary volume; we shall content ourselves with mentioning a few only, as examples of the different groups. Thus, as examples of *Thalamifloræ*—Cruciferæ, Caryophylleæ, and Malvaceæ; of *Calycifloræ*—Rosaceæ, Umbelliferæ, and Compositæ; of *Corollifloræ*—Convolvulaceæ, Solaneæ, and Labiatæ; of *Monochlamydeæ*—Polygoneæ, Urticeæ, and Amentaceæ; of *Phanerogamæ*—Orchideæ, Irideæ, and Gramineæ; of *Cryptogamæ*—Filices, Equisetaceæ, and Lycopodineæ; of *Foliosæ*—Musci and Hepaticæ; and of *Aphyllæ*—Lichenes, Fungi, and Algæ.

In this system it will be observed that De Candolle adopted the primary divisions of Jussieu, but he reversed the order of their arrangement; for instead of commencing with Acotyledons, and passing through Monocotyledons to Dicotyledons, he began with the latter, and proceeded by the Monocotyledons to Acotyledons. He took a retrograde step in placing the Vascular Cryptogams with the Monocotyledons.

Since the appearance of De Candolle's system numerous other arrangements have been proposed by botanists, as those of Agardh, Perleb, Dumortier, Bartling, Lindley, Schultz, Endlicher, and many others. The important work of Robert Brown dates from only a little later than this system of De Candolle. In 1827 he published his discovery of the direct action of the pollen tube on the nucellus of the ovule in Coniferæ and Cycadeæ, which were at that time considered to belong to the Dicotyledons. Thus began the division into Gymnosperms and Angiosperms. At first both these were held to be sections of Dicotyledons, and it was not understood that the Gymnosperms were a lower type. As all these systems, with the exception of those of Lindley and Endlicher, were never much used, and are not adopted in great systematic works

of the present day, it will be unnecessary for us to allude to them further. But the latter having been used in important systematic works, it will be advisable for us to give a general sketch of their leading characters.

Endlicher's Natural System.—The system of Endlicher is adopted in his 'Genera Plantarum,' published between the years 1836–1840. The following is a sketch of this system. He first divided plants into two great divisions, which he denominated Regions, and named Thallophyta and Cormophyta. These were again divided into Sections and Cohorts, as follows:—

Region 1. Thallophyta. Plants with no opposition of stem and root; with no vessels and no sexual organs; and with germinating spores lengthening in all directions.

Section 1. *Protophyta.* Plants developed without soil; drawing nourishment from the element in which they grow; and having a vague fructification; as in Algæ and Lichenes.

Section 2. *Hysterophyta.* Plants formed on languid or decaying organisms; nourished from a matrix; all the organs developing at once, and perishing in a definite manner; as in Fungi.

Region 2. Cormophyta. Plants with stem and root in opposite directions; spiral vessels and sexual organs distinct in the more perfect.

Section 3. *Acrobrya.* Stem growing at the point only, the lower part being unchanged, and only used for conveying fluids.

Cohort 1. *Anophyta.* Having no spiral vessels; both sexes perfect; spores free in spore-cases. Examples, Hepaticæ and Musci.

Cohort 2. *Protophyta.* Having vascular bundles more or less perfect; male sex absent. Spores free in one- or many-celled spore-cases. Examples, Filices and Equisetaceæ.

Cohort 3. *Hysterophyta.* Having perfect sexual organs; seeds without an embryo, polysporous; parasitic. Example, Rhizantheæ.

Section 4. *Amphibrya.* Stem growing at the circumference. Examples, Gramineæ, Liliaceæ, Iridaceæ, Orchidaceæ, and Palmaceæ.

Section 5. *Acramphibrya.* Stem growing at both the apex and circumference.

Cohort 1. *Gymnospermæ.* Ovules naked, receiving impregnation immediately by the micropyle; as in Coniferæ.

Cohort 2. *Apetalæ.* Calyx absent, rudimentary, or simple, calycine or coloured, free or united to the ovary. Examples, Cupuliferæ, Urticaceæ, and Polygoneæ.

Cohort 3. *Gamopetalæ.* Both floral envelopes present, the outer calycine, the inner corolline, the latter being monopetalous; rarely abortive. Examples, Compositæ, Labiatæ, Scrophularineæ, and Ericaceæ.

Cohort 4. *Dialypetalæ.* Both floral envelopes present, the outer being monosepalous or polysepalous, free or united to the ovary, calycine or sometimes corolline; the inner being corolline with distinct petals, or rarely cohering by means of the base of the stamens, and with an epigynous, perigynous, or hypogynous insertion; rarely abortive. Examples, Umbelliferæ, Ranunculaceæ, Cruciferæ, Caryophylleæ, Rosaceæ, and Leguminosæ.

Under these divisions Endlicher included 277 Natural Orders. After Jussieu, he commenced with the simplest plants and gradually proceeded to the more complicated, placing those of the Leguminosæ at the highest point of the series.

Lindley's Natural System.—To Lindley especially belongs the merit of having been the first botanist who made any serious attempt to introduce a natural arrangement of plants into use in this country. The first system proposed by him in 1830 was but a slight modification of that of De Candolle. No attempt was made in this system to form minor groups or divisions of the tribes; but in 1833, in a new system, Lindley arranged the natural orders in groups subordinate to the higher divisions, which were called Nixus (tendencies). These primary divisions were again divided into Sub-classes, Cohorts, and Nixus or groups of nearly allied Natural Orders. In 1838, Lindley again altered his arrangement so far as regarded Exogens; and finally, in the year 1845, further modified his views, and proposed the following scheme, which was that adopted by him in his great work on 'The Vegetable Kingdom.'

1. Asexual, or Flowerless Plants.

Stem and leaves undistinguishable .	Class 1. Thallogens.
Stem and leaves distinguishable . .	Class 2. Acrogens.

2. Sexual, or Flowering Plants.

Fructification springing from a thallus	Class 3. Rhizogens.
Fructification springing from a stem.	
Wood of stem youngest in the centre; cotyledon single.	
Leaves parallel-veined, permanent; wood of the stem always confused	Class 4. Endogens.
Leaves net-veined, deciduous; wood of the stem, when perennial, arranged in a circle with a central pith . . .	Class 5. Dictyogens.
Wood of stem youngest at the circumference, always concentric; cotyledons two or more.	
Seeds quite naked . . .	Class 6. Gymnogens.
Seeds enclosed in seed-vessels .	Class 7. Exogens.

The Exogens were further divided into four sub-classes thus:—

Sub-Class 1. *Diclinous Exogens*, or those with unisexual flowers, and without any customary tendency to form hermaphrodite flowers.

Sub-Class 2. *Hypogynous Exogens*, or those with hermaphrodite or polygamous flowers; and stamens entirely free from the calyx and corolla.

Sub-Class 3. *Perigynous Exogens*, or those with hermaphrodite or polygamous flowers; and with the stamens growing to the side of either the calyx or corolla; ovary superior, or nearly so.

Sub-Class 4. *Epigynous Exogens*, or those with hermaphrodite or polygamous flowers, and with the stamens growing to the side either of the calyx or corolla; ovary inferior, or nearly so.

None of the other classes are divided into sub-classes, but of Endogens four sections are distinguished thus:—

1. Flowers glumaceous (that is to say, composed of bracts not collected in true whorls, but consisting of imbricated colourless or herbaceous scales).
2. Flowers petaloid, or furnished with a true calyx or corolla, or with both, or absolutely naked; unisexual (that is, having sexes altogether in different flowers, without half-formed rudiments of the absent sexes being present).
3. Flowers furnished with a true calyx and corolla; adherent to the ovary; hermaphrodite.
4. Flowers furnished with a true calyx and corolla, free from the ovary; hermaphrodite.

Under the above classes Lindley includes 303 Natural Orders, which are arranged in fifty-six groups subordinate to the sections, sub-classes, and classes, and which are termed Alliances.

BENTHAM AND HOOKER'S SYSTEM.—The essential features of this system for the arrangement of the Phanerogamia, which is adopted in their great work, 'Genera Plantarum,' are as follows:—

Division I. PHANEROGAMIA.
Sub-division 1. ANGIOSPERMIA.
Class 1. *Dicotyledones.*
Sub-Class 1. POLYPETALÆ.
Series 1. Thalamifloræ.
2. Discifloræ.
3. Calycifloræ.
Sub-Class 2. GAMOPETALÆ or MONOPETALÆ.
Series 1. Inferæ or Epigynæ.
2. Superæ.
3. Dicarpeæ.
Sub-Class 3. MONOCHLAMYDEÆ or INCOMPLETÆ.
Series 1. Curvembryæ.
2. Multiovulatæ aquaticæ.
3. Multiovulatæ terrestres.
4. Micrembryæ.
5. Daphnales.
6. Achlamydosporeæ.
7. Unisexuales.
8. Ordines anomali.
Class 2. *Monocotyledones.*
Series 1. Microspermæ.
2. Epigynæ,

Series 3. Coronarieæ.
4. Calycinæ.
5. Nudifloræ.
6. Apocarpæ.
7. Glumaceæ.
Sub-division 2. GYMNOSPERMIA.

The series in the sub-classes Polypetalæ and Gamopetalæ of the above system are further divided into Cohorts as follows: —

Sub-Class 1. POLYPETALÆ.
Series 1. Thalamifloræ.
Cohort 1. Ranales.
2. Parietales.
3. Polygalineæ.
4. Caryophyllineæ.
5. Guttiferales.
6. Malvales.
Series 2. Discifloræ.
Cohort 1. Geraniales.
2. Olacales.
3. Celastrales.
4. Sapindales.
Series 3. Calycifloræ.
Cohort 1. Rosales.
2. Myrtales.
3. Passiflorales.
4. Ficoidales.
5. Umbellales.
Sub-Class 2. GAMOPETALÆ.
Series 1. Inferæ or Epigynæ.
Cohort 1. Rubiales.
2. Asterales.
3. Campanales.
Series 2. Superæ.
Cohort 1. Ericales.
2. Primulales.
3. Ebenales.
Series 3. Dicarpeæ or Bicarpellatæ.
Cohort 1. Gentianales.
2. Polemoniales.
3. Personales.
4. Lamiales.

No division of the series of the Monochlamydeæ or of the Monocotyledons is made in 'Genera Plantarum;' but in the English translation of Le Maout and Decaisne's 'Traité Général de Botanique,' which was edited by Sir J. D. Hooker, another classification of them is adopted as follows:—

Sub-Class 3. MONOCHLAMYDEÆ.
  Division 1. Ovary superior (*Superæ*).
    Cohort 1. Chenopodiales.
      2. Laurales.
      3. Daphnales.
      4. Urticales.
      5. Amentales.
      6. Euphorbiales.
      7. Piperales.
      8. Nepenthales.
  Division 2. Ovary inferior (*Inferæ*).
    Cohort 1. Asarales.
      2. Quernales.
      3. Santalales.

Class 2. *Monocotyledones.*
  Division 1. Ovary inferior (*Inferæ*).
    Cohort 1. Hydrales.
      2. Amomales.
      3. Orchidales.
      4. Taccales.
      5. Narcissales.
      6. Dioscorales.
  Division 2. Ovary superior (*Superæ*).
    Sub-division 1. Ovary apocarpous (*Apocarpæ*).
      Cohort 1. Triurales.
        2. Potamales.
    Sub-division 2. Ovary syncarpous (*Syncarpæ*).
      Cohort 1. Palmales.
        2. Arales.
        3. Liliales.
        4. Pontederales.
        5. Commelynales.
        6. Restiales.
        7. Glumales.

For full particulars in reference to this system, reference should be made to Bentham and Hooker's 'Genera Plantarum,'

and to the English translation of Le Maout and Decaisne's 'Traité Général de Botanique,' edited by Sir J. D. Hooker.

Besides the above systems, others are now much used in Germany, as those of A. Braun and Caruel of the Phanerogamia; and those of Sachs and others of the Cryptogamia.

The most recent system is that put forward by Warming, who divides the Gymnosperms into three classes instead of three natural orders, viz. Coniferæ, Cycadeæ, and Gnetaceæ. The Angiosperms are then divided into Monocotyledons and Dicotyledons. The sub-classes of De Candolle and his successors are abandoned, and Dicotyledons are divided into (1) Choripetalæ, with which are united the old Apetalæ, and (2) Sympetalæ. The Choripetalæ are subdivided into twenty-five families; the Sympetalæ into two sections, Pentacyclicæ and Tetracyclicæ, the former including three families and the latter eight, divided into those with hypogynous and those with epigynous flowers. Monocotyledons are grouped into seven families on somewhat similar lines to those adopted in the older system of Braun, already alluded to.

It will be seen that the Natural System now in use has been gradually evolved through the working of many observers, extending over many years. There is no reason to suppose that it has yet attained anything like completeness; indeed, many of the groups are still variously placed by different botanists. For the present, however, the Vegetable Kingdom may be conveniently divided into the following four groups:—

I. Thallophyta, including the forms whose vegetative body is commonly a thallus or a thalloid shoot. It rarely shows greater morphological differentiation. The prominent form is the gametophyte, the sporophyte not always occurring.

It is subdivided into:

Class 1. Algæ.
„ 2. Fungi.
„ 3. Lichenes.

II. Bryóphyta, or Moss-like plants. The gametophyte is the more prominent form, and regularly alternates with the sporophyte. Differentiation of the body of the former into stem and leaves is general, but the roots are rudimentary or absent.

It includes:

Class 4. Hepaticæ.
„ 5. Musci.

III. Pteridophyta, or Fern-like plants. The sporophyte is the prominent form, the gametophyte being small and not well developed. Considerable differentiation of tissues is found in the sporophyte, and its body exhibits stem, leaves, and roots.

It includes:

Class 6. Filicinæ.
,, 7. Equisetinæ.
,, 8. Lycopodinæ.

IV. Spermaphyta, or Phanerogamia, including all plants which produce seeds. The sporophyte is the predominant form.

The subdivisions are:

A. Gymnospermæ.
Class 9. Gymnospermæ.

B. Angiospermæ.
Class 10. Monocotyledones.
,, 11. Dicotyledones.

CHAPTER III.

Group I.

THALLOPHYTA.

This group includes the Algæ, the Fungi, and the Lichens. It embraces plants of widely different habit and complexity of structure, both morphological and anatomical. In the lowest forms they are characterised by extreme simplicity in both these respects, the plant body being sometimes a single cell, sometimes a thallus consisting of filaments or plates of cells. In the higher forms, on the contrary, the plants are often bulky and formed of masses of tissue showing some considerable histological differentiation; their form may display both root and shoot, the latter exhibiting stem and leaves. Again these bulky masses may be distinctly thalloid.

Fig. 779.

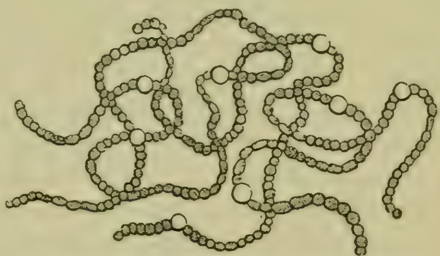


Fig. 779. Filaments from a Nostoc colony. After Luerssen.

The simplest Thallophyte shows no histological differentiation, being only a single cell such as Yeast, or Hæmatococcus. A chain of cells like Nostoc (*fig.* 779) is almost as simple, though cells of different appearance may be present in the chain. Usually a filament of this kind has its cells independent, and separated from each other by cell-walls. In a good many cases these separating walls are not formed, and the organism consists of a tubular body with an external wall, on the inner face of which lie the constituent cells, whose protoplasm is continuous throughout. The composite nature of this structure is recognised by the presence of numerous nuclei. A structure like this is called a *Cœnocyte.*

The filament in other cases is much like this, but some of

the separating walls are present, so that the filament is divided into a number of chambers, which are not cells but cœnocytes.

This cœnocytic structure may extend into some of the morphologically most highly complex bodies. Thus the Alga *Caulerpa*, which attains considerable size and whose body shows rounded stems and much-divided leaves, is composed of only a single cœnocyte, whose cavity extends through all the ramifications of the plant. The Fungus *Mucor mucedo* shows a similar structure (*fig.* 780).

In cases where the Thallophyte is composed of masses of

Fig. 780.

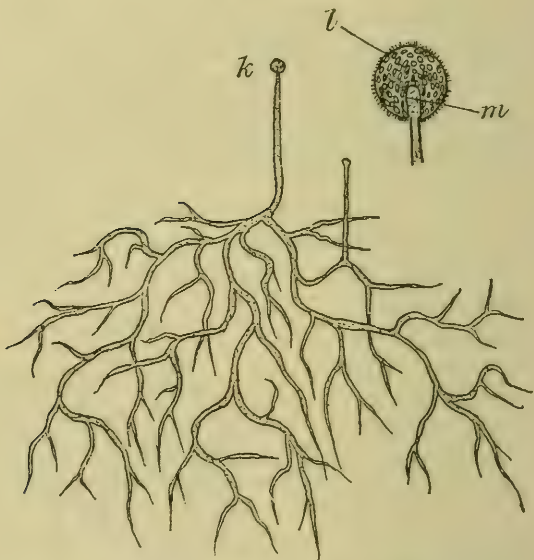


Fig. 780. Cœnocyte of *Mucor mucedo.*

cells there may be considerable histological differentiation, or there may be but little. In some of the brown seaweeds we find a limiting layer, enclosing a very different internal tissue. In some this is composed of elongated loosely arranged cells with mucilaginous cell walls ; in others it shows differentiation into more complex structures. Thus in *Macrocystis* we find under the epidermal layer a layer of thin-walled parenchyma covering a layer of somewhat prosenchymatous cells with thickened walls, sometimes with pits upon them. The inner portion of this contains the well-marked sieve tubes already referred to. Some of the large Algæ of the same group as

Macrocystis, the *Laminarias*, show a secondary growth in thickness of the stalk, the merismatic layer being sometimes the epidermal one, and sometimes one specially differentiated near the periphery. In the latter case the growth in thickness resembles that of *Dracæna*, though the cells formed are different, never becoming lignified nor truly vascular. There is formed in some a kind of axial strand of elongated cells, which can sometimes be traced upwards into the leaves. In some of the plants of the same group certain secretory structures, the *mucus* or *gum passages*, are differentiated. In the masses of tissue constituting the so-called fructifications of the more bulky Fungi, such as *Agaricus*, the structure is composed of filamentous cells or hyphæ arranged side by side and cohering together.

The differentiation of tissue leads also to the localisation of the regions of growth. The growing points may be convex or depressed, when they are apical; or they may be intercalary.

The form in which the plant exists is always the gametophyte. The sporophyte is either not produced at all, or it forms only a small structure not detached from the gametophyte, and sometimes consisting only of a single cell. In only a few cases is it a separate structure. There is thus not that regular alternation of generations which we have seen to exist in all the forms above the Thallophytes, when sporophyte regularly gives rise to gametophyte and is again reproduced from the latter. This obtains, however, in some cases, particularly in the higher Algæ.

The gametophyte in very many cases produces asexual as well as sexual reproductive cells. These are in structure and mode of behaviour almost exactly like the spores of the sporophyte. To distinguish them from the latter they are often called *gonidia*. In some cases both gonidia and gametes are borne upon the same gametophyte; in others the plant frequently produces gonidia alone. A gametophyte in which no sexual cells arise is spoken of as a *potential* one. In many cases a succession of potential gametophytes occurs, each arising from one of the gonidia of its parent, which succession is sooner or later interrupted by one of the series producing sexual cells. Thus an irregular alternation of generations arises, not between gametophyte and sporophyte, but between actual and potential gametophytes. This is spoken of as *homologous* alternation, to distinguish it from the other kind, which is known as *antithetic*.

A potential gametophyte must not be confused with a sporophyte, though both bear only asexual reproductive cells. The

former is capable of bearing sexual cells as well, under appropriate conditions; the latter is not.

As mentioned above, the result of the coalescence of two gametes is sometimes the production of a sporophyte. Very often, however, the process only gives rise to another gametophyte.

The same plant body produces thus both sexual and asexual cells. In this lowly class of plants the allotment of these two varieties of reproductive structures each to its appropriate plant body has not yet been reached.

Above this group each kind is found developed upon its special form, and the two forms regularly alternate.

FIG. 781.

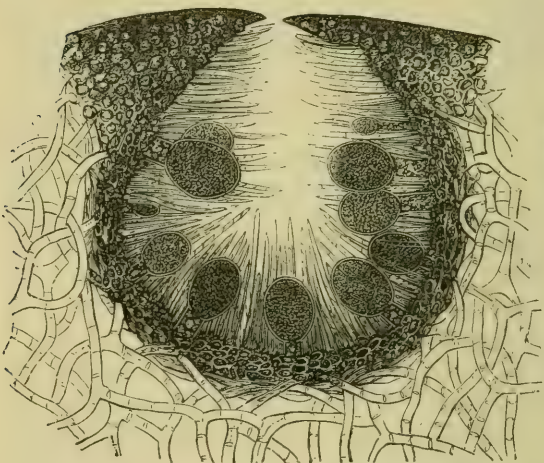


FIG. 782.

Fig. 781. Vertical section of a female conceptacle of *Fucus vesiculosus* containing oogonia and paraphyses. After Thuret.——*Fig.* 782. Oogonium with the oospheres fully separated, and disengaging themselves from their coverings. After Thuret.

The gametophyte is the dominant form in the group; the commencement of the development of the sporophyte is indicated in the group of Algæ by the zygospores of many Chlorophyceæ, which produce two or four zoospores on germination, and by the formation of the cystocarps or fruits of the red seaweeds; in the Fungi by the behaviour of the zygote of the Myxochytridineæ which gives rise to zoospores and that of Mucor which produces a rudimentary mycelium, giving rise at once to a sporangium with its spores.

In the Thallophyta the differentiation of the sexual organs is seldom very complex. The male cells or antherozoids, or spermatozoids, are usually developed in antheridia, often consisting of

single cells of the surface. In the Fungi the differentiation into antherozoids, with one doubtful exception, does not take place, and the male organ is only a swollen cell or branch of a hypha, containing usually undifferentiated protoplasm. In most cases the antherozoids are ciliated and consequently motile; in certain groups of both Algæ and Fungi they are non-motile. In this case they become sooner or later clothed with a cell-wall.

The female organ is usually an *oogonium* (*fig.* 782) consisting of a single cell, often carried on a stalk, and containing one or more *oospheres*. In other forms it is an *archicarp* (*fig.* 783)

Fig. 783.

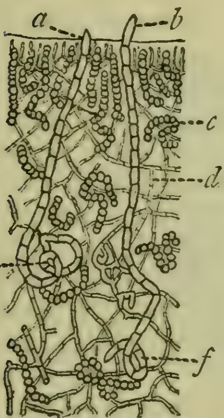


Fig. 784.

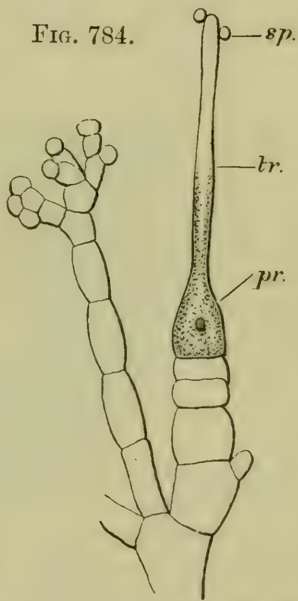


Fig. 783. Section of thallus of a lichen, showing archicarps, *e, f*.——*Fig.* 784. Procarp of one of the Red Seaweeds. *tr.* Trichogyne. *sp.* Spermatia. After Kny.

or *procarpium* (*fig.* 784) and does not contain any differentiated oosphere.

The Thallophyta are divided into three classes, the Algæ, Fungi, and Lichens. The first contain chlorophyll, the second do not. As a consequence their habit of life is essentially different; the former can prepare food for themselves from the constituents of the air and the medium in or on which they live; the latter are compelled to obtain them directly or indirectly from other organisms. The members of the third class are partly algal and partly fungal.

Class I.—ALGÆ.

As we have already seen, there exists in this group a wonderful variety of forms, ranging from single cells of microscopic dimensions to immense plants showing both morphological and anatomical differentiation. They are mainly aquatic in their habit, being found in both fresh and salt water. Many of the humbler of them occur not in water, but in moist situations, such as on rocks, banks, tree trunks, &c. Some few forms are epiphytic, living attached to other Algæ by filamentous or more massive outgrowths, which are embedded in the tissues of their hosts. Though epiphytic they are usually not parasites.

They all contain colouring matters of some kind ; chlorophyll is always present, but in some it is masked by the presence of other pigments in the chromoplastids. We have blue-green, green, brown and red Algæ, and the distinguishing colouring matters serve as a primary basis of classification in the group.

The forms that live in fresh water are chiefly green, though there are among them a few red forms, and many which are blue-green. A large number of microscopic forms, belonging to the Diatoms, also inhabit fresh water. These are olive-brown in colour.

The massive forms include representatives of all four colours : their distribution bears a certain relationship to their hue. Thus the seaweeds which are found near the limit of high-water are green ; between high and low-water marks the olive-brown forms are more prominent, while the red forms are also sparsely represented in this area. Beyond low-water mark the olive-green gradually give place to the red forms, and as the depth increases the latter become predominant. They are seldom found beyond a depth of 250 to 300 feet, so that the massive flora occupies a belt along the shore, extending from that depth to the limit of high water. Some forms are attached to a substratum, others float freely in the water.

The form which the adult plant exhibits is, as we have seen, the gametophyte, either actual or potential. The sporophyte rarely occurs, and then only in the higher members of the green and red forms.

In histological differentiation the Algæ are all very simple as compared with the higher plants. Many of them are

unicellular and multiply by ordinary fission; each cell-division so produces a new plant. In others the cells do not separate from each other, but the division proceeds until a long filament of cells is formed, each cell being generally physiologically independent, though connected anatomically with the others. In other cases the cells divide in two planes, forming a plate of cells. Sometimes the unicellular forms do not separate from each other after division, but remain connected by a common mucilaginous cell-wall, forming a colony or *cœnobium*. In other Algæ the structure is a cœnocyte, no cell-walls being formed in the interior of the filament, which thus appears unicellular. In the larger cœnocytes, as *Caulerpa*, the cavity is often crossed by

Fig. 785.

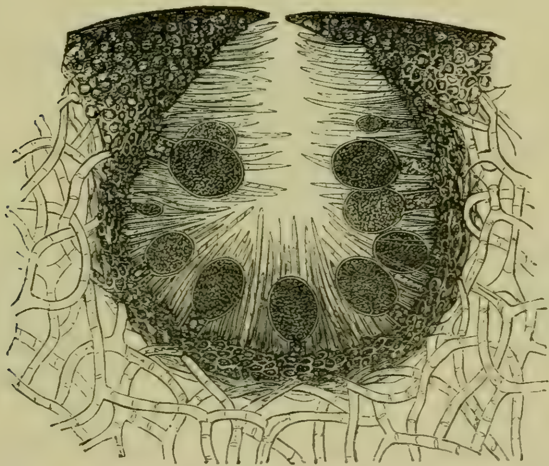


Fig. 785. Vertical section of a female conceptacle of *Fucus vesiculosus* containing oogonia and paraphyses. After Thuret.

trabeculæ of modified cellulose. In the higher forms the plant is multicellular, and shows a rudimentary differentiation of tissues; a kind of epidermis often being distinguishable from a central tissue, which is sometimes furnished with sieve-tubes. In the stalks of some Laminarias there is a secondary meristem which increases the thickness of the part. In many of the Phæophyceæ the internal cells are hypha-like, and loosely arranged with mucilaginous walls and large intercellular spaces (*fig.* 785). There is sometimes a fair amount of morphological differentiation; generally the plant body is a thallus, but frequently rudimentary roots can be distinguished, serving as organs of attachment. The plant is often attached to its substratum by

special discs or outgrowths from the stem known as *haptera*. The shoot in many cases may show differentiation into stem and leaf, sometimes of very delicate form. Instances may be found in *Caulerpa*, *Chara*, *Sargassum*, and others.

The mode of growth in length of the thallus or thalloid shoot also varies a good deal. There are often definite growing points, which may be either apical or intercalary. When they are apical they sometimes consist of a simple apical cell, as they do in the Ferns and their allies ; or they may be composed of a number of cells. These may be disposed in a series along the margin of the thallus, or may form a group resembling the apical meristem of the Phanerogams. In the cœnocytes, though these grow at their apices, no apical cell is differentiated. When the growth in length is intercalary there is often a definite growing zone in the frond, but sometimes this is not the case, any cell being capable of division. Sometimes the growing point consists of a terminal hair, or collection of hairs, the basal cells of which are merismatic. In most filamentous forms, any cell of the filament can divide, and so increase the length of the filament.

Where secondary growth in thickness takes place it may be brought about in two ways. In the stalks of some of the Laminarias a secondary meristem or cambium is developed, either in the epidermal cells or those immediately beneath them. This behaves as in woody Dicotyledons, producing new tissue on both sides. The external tissue forms a pseudo-bark or rind, while the internal adds to the substance of the stalk. The central stalk tissue is a dense plexus of filaments which anastomose freely with each other. In *Desmarestia* a sort of mantle or covering of the original axis is produced by filaments which grow from the cells of the lateral branches originating just below the growing point, which become united together and to the original axis, subsequently undergoing differentiation with cortical and internal tissues.

With the exception of the lowest group the colouring matters are associated with definite chromatophores, which may occur singly or in numbers in the cells. The pigments which are formed are *phycoerythrine* in the red, *phycoxanthine* and *phycophæine* in the brown, and *phycocyanine* in the blue-green Algæ. Besides these, all the members of the group contain chlorophyll, which is the only colouring matter in the green forms. The other pigments may be extracted by fresh cold water, which dissolves all but the chlorophyll. The disposition

of the chromatophores is very constant in the several species. In some of them curious bodies called *pyrenoids* are found, which are probably connected with the assimilative processes.

The group exhibits considerable variety in its modes of sexual reproduction. In the simplest forms that show sexuality, the gametes are not distinguishable into male and female. In Ulothrix (*fig.* 803) the contents of some cells break up into a number of ciliated masses of protoplasm which escape from the cell, and, after swimming about for a while, conjugate in pairs. In the Zygnemeæ and Mesocarpeæ the gametes are solitary and not motile, and do not escape from the cells in

Fig. 786.

Fig. 787.

Fig. 788.

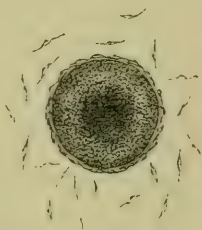


Fig. 786. Antheridia, *a*, *a*, on the branched hairs of the male conceptacle. After Thuret.——*Fig.* 787. Oogonium with the oospheres fully separated, and disengaging themselves from their coverings. After Thuret.——*Fig.* 788. An oosphere without a cellulose coat being fertilised by antherozoids so as to form an oospore.

which they are formed. In Cutleria the gametes are dissimilar in size, but both are ciliated. The larger comes to rest soonest, and one of the smaller fuses with it. More completely differentiated gametes are found in higher forms (*figs.* 787 and 789); oospheres are developed in oogonia and antherozoids in antheridia. When the gametes are alike the reproduction is called *isogamous*; when they are different in size and behaviour it is said to be *oogamous*. In the Rhodophyceæ the antherozoid is not ciliated and there is no differentiated oosphere. Instead of an oogonium the female organ is known as a *carpogonium*. It is frequently multicellular, and fertilisation is brought about through a filiform or elongated cell known as a trichogyne.

The asexual reproductive cells are frequently borne upon the gametophyte. They may be ciliated cells, differing but

FIG. 789.

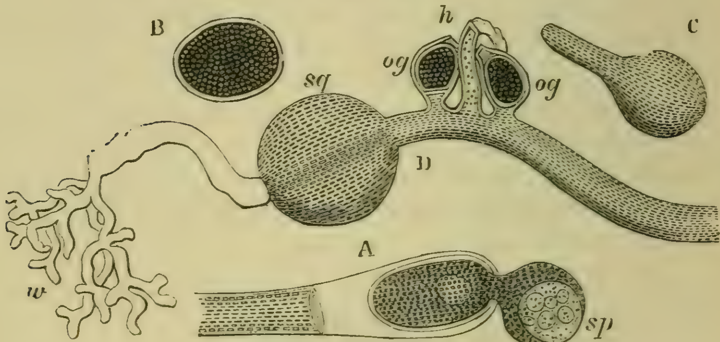


Fig. 789. A. *sp.* Newly formed zoospore or zoogonidium of *Vaucheria sessilis* escaping. B. Zoospore at rest after having lost its cilia. C. First stage of germination. D. Filament of *Vaucheria sessilis* producing oogonia, *og*, and antheridium, *h*. *w.* Hyaline root-like process, forming a sort of mycelium. *sq.* Zoospore, which by germinating has formed the filament. After Sachs.

FIG. 790.

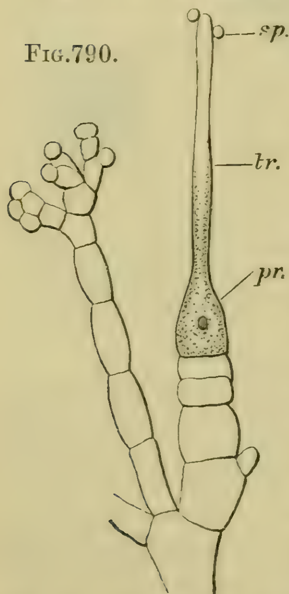


Fig. 790. Procarp of one of the Red Seaweeds. *tr.* Trichogyne. *sp.* Spermatia. After Kny.

little, if at all, in appearance from the gametes. These are known as zoogonidia, from their power of movement. In other cases they are non-motile. They are at first always naked cells. Sometimes they are developed in special organs, the *gonidangia*; in some forms any cell of the thallus may produce them. Where the sporophyte exists it gives rise to spores similar in structure to the gonidia. In many of the green Algæ the zygospore or oospore gives rise to a number of zoospores, either with or without preliminary cell-division. It must in such cases be regarded as a very rudimentary sporophyte.

Vegetative reproduction is very common in the lower forms; in the unicellular Algæ, each cell-division is often followed by a separation of the cells, showing thus the simplest example of this mode. In *Sphacelaria*, gemmæ are

produced which are multicellular. *Chara* gives rise also to peculiar structures, the *embryonic branches*, which are referable to this mode of reproduction.

The main sub-divisions of the Algæ are based upon the colour of the thallus. This distinction would be of little value in itself, but the groups so defined show peculiarities of form and of life history which warrant their being considered as sub-classes. The divisions are Cyanophyceæ (blue green), Chlorophyceæ (green), Phæophyceæ, and Diatomaceæ (olive-brown), and Rhodophyceæ (red).

Sub-Class I.—Cyanophyceæ.

The forms presented by the members of this group are very simple. In many cases the plant is unicellular, or if it divides, the products of the division remain surrounded by a common cell-wall, which becomes mucilaginous and of considerable thickness, so that the cells appear as if embedded in a mass of jelly. The plane of division may be such as to cause the cells to form a flat plate, or a mass more than one cell in thickness may result. In other cases the cells divide so as to form a filament, often of some length, sometimes tapering at its apex, which may be either free or attached at its base to some substratum. Many filaments usually are collected together, so that the plant appears in tufts. This filamentous form is also invested with a sheath, of similar consistence to that in the former case. The sheath is often coloured with various tints, purple, blueish, or red. The cells are not ciliated, but the filaments are capable of a peculiar swaying movement, the mechanism of which is not known. The cells are in all cases of very simple structure; no nucleus has been satisfactorily shown to exist, and the phycocyanin or blue-green colouring matter is diffused through the protoplasm; no chromoplastids have been found. The cell-wall has been stated to be formed of a substance resembling cutin, while the sheath is always cellulose, or a modification of it. The reproductive processes are chiefly vegetative; the filaments split up into fragments, which, after a period of inactivity, grow out into filaments like their parent. These fragments, which consist of several cells, are called *hormogonia*. In one section of the sub-class, to which Nostoc belongs, the cells of the filament are of two kinds (*fig.* 791); here and there in the course of the filament large, almost spherical clear cells appear, which are named *heterocysts*. These mark the limits of the hormogonia.

The filament sometimes branches, either regularly by the

formation of growing points placed laterally, or irregularly often by the hormogonia not becoming completely detached, and so growing while adhering to the filament.

In many forms spores are produced. These are single cells of the filament or mass, which are rounded in shape, larger than the other cells, and furnished with a strong thickened cell-wall. They become detached from the plant, and are capable of resting for some time before germinating. In the filamentous forms, when germination takes place, the wall of the spore cracks and cell-divisions take place in the cell in such order that a filament is produced much resembling an ordinary hormogonium, which becomes set free from the spore-coating and develops into the plant. In the other forms, the divisions of the germinating spore are irregular and give rise to a mass of cells. Sexual reproduction is unknown in the group.

Fig. 791.

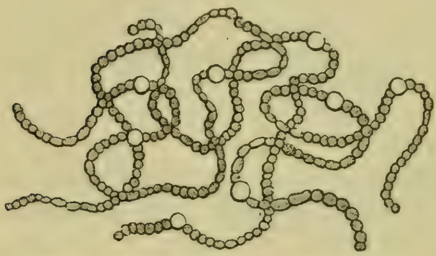


Fig. 791. Filaments from a *Nostoc* colony. After Luerssen.

In habit, some of the Cyanophyceæ are free floating organisms; others are attached by their bases to rocks or stones. Some are embedded by their gelatinous coatings to form colonies of various shapes. Some are endophytic and live symbiotically with other plants. Thus Nostoc is frequently found associated with a fungus in the thallus of a lichen; it occurs, too, in cavities in the thallus of Azolla and in the body of Anthoceros. Others again are epiphytic, boring into the tissue of other Algæ and remaining attached to them. A few of them, chiefly abundant in hot springs, are covered with a precipitate or pellicle of carbonate of calcium, which may wrap round the individual filaments, or enclose the whole thallus.

Sub-Class II.—Diatomaceæ.

These plants have often been included in the next sub-class, the Phæophyceæ, on account of their olive-brown colour. They are, however, so unlike them in every other respect, while they present no very great resemblance to any other group of Algæ, that it seems best to regard them as a separate sub-class.

They are both fresh-water and marine in their habit, and are extremely numerous wherever they occur.

Diatoms are unicellular plants, of very minute size, which have their cell-walls strongly impregnated with silica, the markings upon the walls often being of great regularity and beauty. The plants may be free, or a number of them may be grouped together. In the latter case the colony may consist of a chain of cells, or they may be aggregated together upon gelatinous stalks, or may form gelatinous masses. Each diatom consists of a protoplasmic cell or *frustule* which is encased in two silicified shells known as valves, one of which overlaps the other by its edges. The peculiar sculpturing is found upon the flattened face of each valve. The plant is not furnished with cilia, but is nevertheless capable of a peculiar gliding movement through the water, the nature of which is at present unexplained. The colouring matter is deposited in chromatophores of more or less regular form, and is not diffused through the protoplasm as in the preceding group.

The diatoms frequently undergo longitudinal fission; the two valves slightly separate; the protoplasm divides, and each half secretes a new valve between itself and its fellow, which has its edges included under the rim of the old valve. The two valves of a diatom are thus of different ages. In the free forms this process of fission increases the number of the individuals; in those which continue attached it recalls the processes of intercalary growth.

This repeated bi-partition gradually reduces the size of the diatoms, each new valve being necessarily a little smaller than the one which overlaps it. When a certain limit of size is reached another method of reproduction occurs, which is in some cases a sexual one. This is the formation of *auxospores*. The contents of two diatoms escape from their containing valves and unite together, growing into a new plant which secretes a pair of valves like those of the original cells. In some cases the process is asexual; the contents of a cell escape and grow; on a considerable size being attained, new valves are secreted by the protoplasm and the original appearance is resumed.

Certain modifications of both these methods occasionally occur.

Sub-Class III.—Phæophyceæ, or Melanophyceæ.

This sub-class includes those Algæ which are of an olive-brown or olive-green colour, with the exception of the Diatomaceæ. Its members comprise forms of very great variety,

some being microscopic while others have a plant body several hundreds of feet in length and of considerable thickness. In the simplest cases the body is unicellular, or forms a colony resembling that of many of the Cyanophyceæ. The colony may be attached or not. In other cases the plants, which vary a good deal in size, are attached to rocks by specially differentiated roots, or by haptera. Epiphytic forms occur, filamentous patches being seen upon other Algæ ; these are the free portions of the epiphyte, rhizoidal appendages having penetrated the tissues of the host.

The brown colouring matter, which is a mixture of phycophæine and phycoxanthine, is localised in definite plastids or chromatophores, instead of being diffused through the protoplasm of the cells. The anatomical or histological differentiation is sometimes considerable, a great variety of tissues being found in the thallus.

Asexual reproductive cells are found in some of the members of this sub-class, which may be spores or gonidia; sometimes these are motile, sometimes not. Some members of the group possess only sexual reproductive cells.

The sexual organs are sometimes *antheridia*, containing *antherozoids*, and *oogonia*, producing *oospheres*. Fertilisation never takes place in the oogonia, the gametes of both sexes being discharged with the water. The antherozoids are ciliated, the cilia being two in number, attached at the side of the gamete and pointing one towards each end.

More frequently the gametes are alike, or nearly so, when the organ producing them is called a *gametangium*. They are then always ciliated.

The oogonium is always unicellular and produces one or several oospheres; the antheridium may be unicellular or multicellular. In the latter case each cell produces only a single antherozoid.

There is a good deal of variety in the morphological differentiation of the group. Some show only a thallus; others present the appearance of root and shoot, and in many the latter is distinctly leafy. In some, special branches bear the reproductive organs.

Alternation of generations can only be traced in some forms ; the sporophyte phase is generally absent; it is represented in some of the Cutleriaceæ, though sometimes the two forms are very similar in appearance and can only be distinguished by noticing what kind of reproductive cells they respectively produce.

The sub-divisions of the group are very difficult to define, and many schemes of classification have been suggested.

Several different types may with advantage be considered. Of these the FUCACEÆ are most familiar. The thallus is generally of large size and shows a copious branching. In *Cystoseira* and other genera the shoot can be seen to be divided into stem and leaves. *Sargassum* exhibits also the fruiting branches spoken of above. The branches of the thalloid shoot, or the leaves of the leafy forms, often exhibit curious air-chambers which serve as floats. The plants are often attached to the substratum by suckers, or by haptera. The epiphytic forms are secured to their hosts by haustoria, which penetrate the tissues of the latter.

The thallus generally shows histological differentiation. There is an external rind of closely packed cells, in which the colouring matter is abundant. This constitutes a pseudo-epidermis. The innermost layer of this tissue is capable of increasing the thickness of the shoot by repeated tangential divisions, forming in some cases almost a rudimentary bark. Beneath this layer is some thick-walled parenchyma ; and this covers in turn a central strand, often of considerable dimensions. The cells of this strand are elongated and narrow, and have their longitudinal walls pitted. They do not, however, become woody, but their walls are usually mucilaginous and much swollen.

Growth in length is carried out by means of an apical cell, which is placed at the bottom of a pit or depression at the apex (*fig.* 792). The branching may be lateral or dichotomous.

The reproductive organs are variously situated, but always occur in peculiar depressions of the surface known as *conceptacles* (*fig.* 793 *t*). These are nearly globular cavities in the thallus which open to the surface by small pores or apertures known as *ostioles*. They are developed near the growing point. One or more cells cease to grow, and by the continued increase in size and number of those adjoining them a pit is formed which becomes ultimately the cavity of the conceptacle. The distribution of the sexual organs in the conceptacles varies in different species. In some, antheridia or oogonia arise in each ; in others the same conceptacle may contain both.

The cells at the bottom of the conceptacle grow out into hairs, from some of which the sexual organs arise. The antheridia are formed in great numbers as the terminal cells of branches of these hairs (*fig.* 795). Each produces a number of bi-ciliated

antherozoids, which are sometimes discharged into the conceptacle and make their way out through the ostiole. In other cases the antheridia are detached unruptured and escape from the conceptacle, the antherozoids being subsequently liberated.

The oogonia arise from two-celled hairs, of which the upper cell only gives rise to the sexual organ, the lower one forming a stalk to it (*fig.* 794). Each oogonium develops usually eight oospheres, of generally spherical shape and having no cilia. The wall of the oogonium is composed of two layers, and when the oospheres are mature the outer layer bursts (*fig.* 796), and the

Fig. 792.

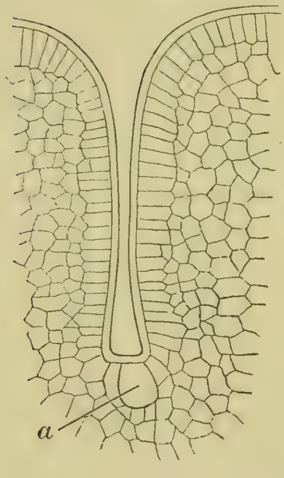


Fig. 793.

Fig. 792. Growing point of *Pelvetia*. *a.* Apical cell. After Kny.——*Fig.* 793. Thallus or thallome of the common Bladder Seaweed (*Fucus vesiculosus*). *t, t.* Groups of conceptacles. *v, v.* Bladders of air.

inner one, covering the oospheres, is extruded. When this bursts later the latter are set free into the water. Fertilisation always takes place outside the conceptacle, each oosphere becoming surrounded by a number of the ciliated antherozoids (*fig.* 797), one of which ultimately fuses with it, forming the oospore or zygote, which then secretes for itself a cellulose covering. The zygote generally germinates at once.

Besides the sexual organs the conceptacles contain a number of barren hairs or paraphyses (*fig.* 794), which frequently are so numerous towards the top of the cavity as to protrude through the ostiole.

Certain conceptacles in some of the Fucaceæ do not give rise to sexual organs. These are generally known as *cryptostomata.*

FIG. 794.

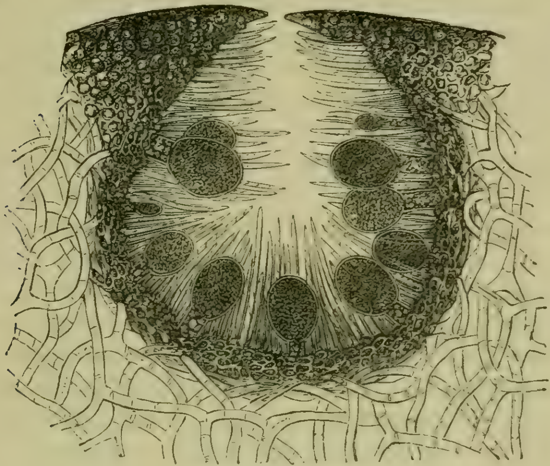


FIG. 796.

FIG. 795.

FIG. 797.

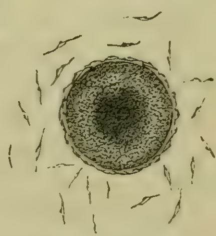


Fig. 794. Vertical section of a female conceptacle of *Fucus vesiculosus* containing oogonia and paraphyses. After Thuret.——*Fig.* 795. Antheridia, *a*, *a*, on the branched hairs of the male conceptacle. After Thuret.——*Fig.* 796. Oogonium with the oospheres fully separated, and disengaging themselves from their coverings. After Thuret.——*Fig.* 797. An oosphere without a cellulose coat being fertilised by antherozoids so as to form an oospore.

These cavities contain only paraphyses, which are of greater length than those in the fertile conceptacles.

The LAMINARIACEÆ afford examples of the largest Algæ of the

Phæophyceæ ; they show a good deal of variety of form, including long unbranched fronds terminating below in a thick stalk, as well as stems which bear a series of much and variously divided leaves. In some the stalk is so short and covered by rootlets, while the fronds are so long, that a single plant appears like a group of the unbranched forms. On the stalk, in some cases, gonidiophylls are developed in addition to the ordinary fronds, their development being acropetal. In some of the fronds midribs and subordinate veins appear, giving them a very leaf-like appearance. A few forms possess air-floats, something like those of the Fucaceæ. The stem or stalk terminates below in strong rootlets or haptera, which fasten the plant to a substratum of rock or stone.

The thallus shows still more complete histological differentiation than that of the Fucaceæ. The stalk shows epidermal, cortical, and medullary tissue. The epidermal layer often becomes merismatic, though in many species the meristem is found in the peripheral part of the cortex. This merismatic layer is often very active and causes the stalk to become of considerable thickness. Like most merismatic layers, it forms new tissue on both its faces. The inner portion of the cortex in the stalk consists of a layer or cylinder of elongated cells whose walls are generally pitted. In *Macrocystis* it contains the peculiar sieve-tubes of which mention has already been made.

The central strand is something like that of the larger Fucaceæ, consisting of hypha-like filaments which anastomose copiously. This layer is continued upwards into the fronds.

The mucus passages already alluded to are only found in some of the Laminariaceæ. They are long tubes which branch and anastomose, forming a network in the tissue.

The growing point is sometimes apical, sometimes intercalary.

The reproductive organs are not produced in conceptacles but in sori, variously distributed over the fronds, but sometimes confined to definite sporophylls. Each sorus consists of a number of unilocular gonidangia, among which are found paraphyses. The gonidangia give rise to ciliated zoogonidia or zoospores. Some of the genera possess cryptostomata, which bear paraphyses as in the Fucaceæ.

The genus *Splachnidium* appears to occupy an intermediate position between Fucaceæ and Laminariaceæ. It is peculiar in that it bears sporangia or gonidangia resembling those of the

latter group, which are developed, not in sori, but in conceptacles much like those of Fucus.

The CUTLERIACEÆ have a special interest as illustrating the evolution of sex in the Phæophyceæ. They possess two kinds of gametes which are both ciliated, the female, generally called oospheres, being much larger than the male. The organs in which they arise are situated in sori on the surface of the thallus, and the gametes are set free by a lateral aperture in the wall. When they are liberated both kinds are freely motile; the female comes soonest to rest, and is fertilised by the fusion of an antherozoid with it.

The thallus is sometimes erect and sometimes prostrate. It grows by means of a cluster of hairs, the bases of which are merismatic. The rows of cells produced from each hair become united together laterally to form the tissue of the thallus.

The differentiation of the internal tissue is not so complete as in the other groups described. In Cutleria itself three systems can be seen; the epidermal layer, which contains chromoplastids in abundance, a cortical layer, of clearer cells in which a little colouring matter is present, and an axial layer of larger cells, almost colourless. All the cells are parenchymatous, the pseudo-vessels of the former groups not being represented.

Asexual reproductive structures are met with in the Cutleriacitæ, which take the form of unilocular sporangia, each containing several zoospores. These resemble the gametes in being ciliated, but they are intermediate in size between the antherozoids and the oospheres. In the genus *Cutleria* these are borne upon the young plant produced from the germinating zygote. The form of this sporophyte differs considerably from the thallus which bears the sexual cells. There is thus in Cutleria an alternation of generations. In the other genus of the group, *Zanardinia*, the two forms are essentially similar.

The sexual organs are placed in sori, and originate in hair-like outgrowths of the thallus. The hairs bearing antheridia are often much branched, as in the case of Fucus. The sori contain paraphyses as well as sexual organs.

The DICTYOTACEÆ form a group somewhat resembling the Cutleriaceæ, but differ in the gametes being nonciliated. The thallus is very varied in form, but is generally flattened. The branching is dichotomous, and usually arises from a longitudinal division of a small-celled apical meristem. A single apical cell is only known in the genus *Dictyota*. There is not much differentiation of internal tissue, an epidermis being however well

marked off from a colourless internal mass. The sexual organs are antheridia and oogonia, and are grouped together in sori. The asexual ones are gonidangia, which occur in clusters or scattered over the surface of the thallus. The gonidia and both forms of gamete are nonciliated and motionless. In some forms the reproductive cell, whether sexual or asexual, gives rise to a plant like the parent; in others a kind of filamentous body is developed, recalling the protonema of the Bryophyta, to be described later. The adult plant arises as an outgrowth from some of the cells of this filament.

The spores are often produced in groups of four in the sporangia. In this point and in the unciliated character of the antherozoids the Dictyotaceæ approach the group of the Rhodophyceæ.

The SYNGENETICÆ form a group which is in marked contrast with the rest of the Phæophyceæ. They are unicellular organisms, and resemble the Cyanophyceæ in forming colonies in consequence of the cells not separating after division, but remaining surrounded by their diffluent mucilaginous cell-walls. They have no sexual reproduction, but bear asexual spores, which are ciliated.

Sub-Class IV.—RHODOPHYCEÆ.

This sub-class includes a large number of forms, nearly all of which are marine. They are found growing mixed with olive-green or brown forms at low-water mark and a little beyond, and in deeper water they occur almost alone. The fresh-water forms are few and belong only to two or three families. Some marine forms are parasitic on other red Algæ; others are epiphytic. Some members of this family have the thallus encrusted or impregnated with carbonate of lime, forming structures which superficially resemble the animal corals.

The morphological differentiation of the group is greatly in excess of their anatomical complexity. They are all multicellular, and generally form a much-branched thallus, which may be flattened and spreading, or may be filamentous. The segments of the shoot may in many cases be called leaves, and a root can usually be found.

The histological differentiation is much slighter than in the last group. The filamentous forms sometimes show nothing more than a single row of cells; sometimes there are several such rows, which may be covered by a kind of cortex composed of small cells. In these cases the rows of the filaments do not

form a true tissue, but are bound together by a kind of intercellular substance, or are surrounded by a common gelatinous coating. Each row of cells grows by division of the terminal one, which is sometimes much larger than the others. There is no intercalary growth of the filament by division of any of the other cells, though lateral branches may arise from them. The successive cells of the row or rows constituting the thallus communicate with each other by a kind of rudimentary sieve-plate (*fig.* 798), though they can hardly be described as sieve-tubes.

FIG. 798.

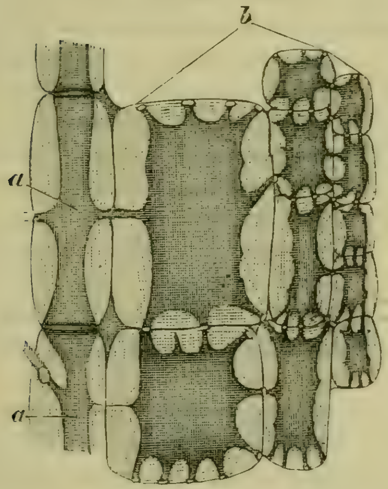


FIG. 799.

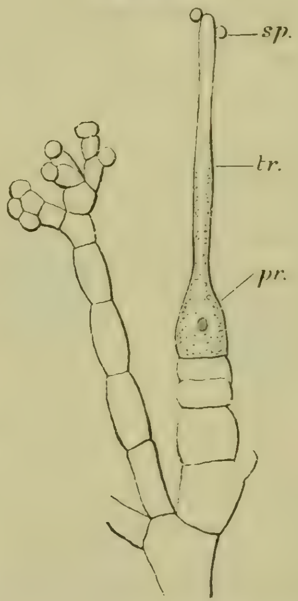


Fig. 798. Semi-diagrammatic longitudinal section of an old and stout portion of *Ceramium rubrum*, showing continuity between the protoplasmic contents of the axial or central cells, *a*, *a*, at their ends; and laterally with the cortical cells, *b*, by protoplasmic threads, and also that of the cortical cells *inter se* by threads radiating from the central mass in each cell. After T. Hick. ——*Fig.* 799. Procarp of one of the Red Seaweeds. *tr.* Trichogyne. *sp.* Spermatia. The branch to the left bears a cluster of antheridia. After Kny.

The flattened forms usually grow at their margins, new cells arising from divisions in certain cells in definite positions there. The characteristic colouring matter is red, and is found in chromatophores in the cells. As in the last group, chlorophyll is present in addition to the phycoerythrine.

The group is characterised by great peculiarity in its methods of reproduction, which are both sexual and asexual.

The gametophyte bears sexual organs and gonidia, the latter

sometimes occurring only in special forms. There is a sporophyte developed after fertilisation of the contents of the female organ, but this is always a very small structure, incapable of great development, and almost at once producing its spores.

The sexual organs are antheridia and carpogonia or procarpia. The antheridia are borne generally in clusters, which are often situated at the end of a filament (*fig.* 799), but which may be collected into various groups upon the surface when the thallus is flattened. Sometimes they are found in pits or depressions of the surface, something like the conceptacles of Fucus. Each antheridium produces externally a number of special cells in which the male gametes are produced singly. The gamete is a mass of protoplasm, which at first in most cases has no cell-wall, but which secretes one after its liberation from the mother-cell, usually just before it reaches the female organ. The term applied to the male gamete is *pollinoid* or *spermatium*; it differs from the antherozoids of the former group in not possessing cilia. The pollinoids are discharged from the antheridial cells by the latter opening at their apices.

Some botanists hold that the structure described above as an antheridium is really a cluster of them, and that the true antheridium is the special cell alluded to. On this hypothesis the antheridia are numerous and unicellular, and give rise each to a single pollinoid.

The female organ, or carpogonium, is peculiar in that it never produces an oosphere, but its contents remain undifferentiated. It is usually a cell with a somewhat swollen base and a long narrow pointed apex. The latter is called the *trichogyne* (*fig.* 799 *tr*), and is the part which is concerned in the act of fertilisation. The carpogonium proper is usually the terminal cell of a short branch consisting of three or four modified cells which are sometimes sunk in the thallus. When the carpogonium is mature a pollinoid comes into contact with the trichogyne, which always projects above the surface of the thallus, even if the whole carpogonial branch is not exposed. The wall of the pollinoid and that of the trichogyne become absorbed at the point of contact, and the contents of the former pass into the cavity of the latter. The further stages of the process have not been observed, but as there is no differentiated oosphere it is probable that the nucleus of the pollinoid fuses with that of the carpogonial cell. The trichogyne becomes cut off from the rest of the carpogonium and withers away.

Fertilisation having been thus accomplished, the further deve-

lopment of the structure varies very greatly in different groups, leading in all ultimately to the production of a fruit-like structure which is known as a *cystocarp*, and which is really the sporophyte phase of the plant. It consists essentially of a cluster of *carposporangia*, variously arranged and often enclosed in a definite encasement of filaments or cells. There are five different types of formation. The first is seen in the NEMALIONACEÆ; here from the fertilised carpogonium filaments known as *gonimoblasts* grow out, often in dense clusters. The terminal cells of the filaments are the carposporangia, and each produces internally a single carpospore. The whole group constitutes the cystocarp (*fig.* 800), which is consequently not enclosed in any specially differentiated case. Sometimes the gonimoblasts arise from the upper part of the carpogonium, sometimes from its side. In some of the families the cystocarp is immersed in the tissue of the thallus. In the Gelideæ the cells of the gonimoblast become united here and there to certain cells of the thallus, from which it absorbs nourishment.

FIG. 800.

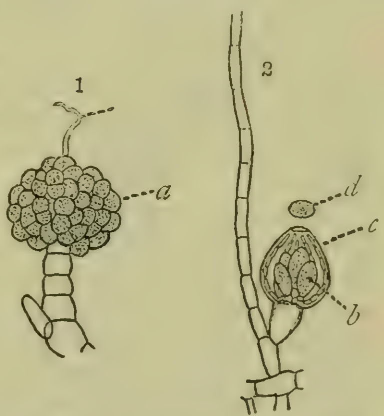


Fig. 800. 1. Cystocarp of Nemalion. *a.* Carpospores.
2. Cystocarp of Lejolisia. *b.* Carpospores. *c.* Wall of cystocarp. *d.* Carpospore escaping. After Kny.

The second type is furnished by the GIGARTINACEÆ; in this, besides the branches which carry the carpogonia, other special cells are produced on the thallus near them, generally in pairs. These cells are known as *auxiliary cells*. When the carpogonium has been fertilised it does not give rise at once to gonimoblasts, but puts out a short protuberance known as an *ooblastema filament*. This makes its way to an auxiliary cell, and the contents of the two fuse. The gonimoblasts arise from the resulting cell and branch in the interior of the thallus, the cystocarp being thus embedded in its substance. The fruit thus arises from the auxiliary cell rather than immediately from the carpogonium as in the Nemalionaceæ.

The third type, characteristic of the RHODOMENIACEÆ, is still more complex. The formation of the cystocarp is indirect as in the last case, the carpogonium conjugating with an auxiliary cell.

A complex procarpium is formed, consisting of carpogonial branches and certain cells which ultimately give rise to the auxiliary cells. The latter are not developed till after the fertilisation of the carpogonium. When they are complete, conjugation takes place between an ooblastema filament from the carpogonium and either the auxiliary cell or a process growing out from it. In some cases the carpogonial and auxiliary cells coalesce without the intervention of either outgrowth. After the process of conjugation is accomplished, gonimoblasts grow out from the resulting cell and form a much-branched collection of filaments which generally protrude from the thallus. Each gives rise to a number of carposporangia. The thallus tissue sends out filaments which coalesce round the cystocarp, forming a protecting wall or case (*fig.* 800, *Lejolisia*). In some cases where the cystocarp is formed upon a slender leaf-like branch of the thallus the filaments proceed from near the cell which bears the carpogonial branch and curling over the latter cover it in. The wall generally begins to be formed as soon as the carpogonium is fertilised. In some cases no protective coating is formed.

The most complicated type is met with in the CRYPTONEMIACEÆ. The fertilised carpogonium sends out a very long ooblastema filament which branches copiously, and consists of several cells. There are many auxiliary cells formed upon separate branches, and one ooblastema filament communicates with several of them, fertilising several in succession. From each of these gonimoblasts proceed; and these branch repeatedly, the cells of the branches forming carposporangia, each containing a single carpospore. The gonimoblasts ramify in the substance of the thallus, so that the fructification is internal, and surrounded by thallus tissue.

The CORALLINEÆ form a very special family of this group. Their thallus, which is of very various form, is encrusted or impregnated with carbonate of lime, the coating covering every part except the reproductive organs. They bear curious cystocarps, which are really compound, and resemble the conceptacles of Fucus. In the hollow of the conceptacle, which opens apically, several carpogonia occur, each with its trichogyne. Other filaments only produce auxiliary cells. After a carpogonium has been fertilised it fuses with many of the auxiliary cells by means of a single ooblastema filament, and a single large cell is formed. The gonimoblasts, each of which bears a chain of carposporangia, arise in some numbers from the

periphery of this cell. The cystocarp is surrounded by the wall of the conceptacle.

In the last type, that of the BANGIACEÆ, the formation is simple and direct, as in the Nemalionaceæ. The carpogonial cells are very little specialised, and only differ from the ordinary cells of the thallus by being a little larger. They grow outwards and give rise to a very rudimentary trichogyne, which becomes fused with a pollinoid as in the other groups. The fertilised carpogonium does not put out a gonimoblast, but either becomes at once a carposporangium, or divides into a number of cells, each of which may be regarded as one. The cystocarp consists merely of the cluster of sporangia, no wall being formed.

The asexual cells of the gametophyte are usually produced in groups of four in a gonidangium. They are variously arranged (*fig.* 801), sometimes being formed in tetrads, sometimes in rows, and sometimes being quadrants of a sphere. They may occur within the cortical region of the thallus, or may be produced upon special hair-like outgrowths. The gametophyte in which they occur is very frequently a potential one, and when they germinate each gives rise to another potential individual. There is thus a succession of potential gametophytes, before an individual appears which bears sexual organs. This kind of alternation of generations has already been alluded to as *homologous* alternation.

FIG. 801.

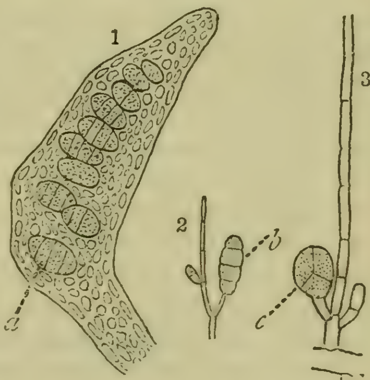


Fig. 801. Tetraspores of Rhodophyceæ 1. Plocamium. 2. Dudresnaya. 3. Lejolisia. (2 and 3 after Kny.)

The gonidia differ from the carpospores in not being clothed with a cell-wall on their liberation. From their occurrence in groups of four they are usually termed tetraspores, or tetragonidia.

Sub-Class V.—CHLOROPHYCEÆ.

In many respects this group may be considered to approach most nearly the next great division of plants, the Bryophyta, as in the higher forms the oosphere is fertilised in the oogonium and not after extrusion from the plant. Though as a rule both

anatomical and morphological differentiation is but slight, the peculiarities of sexual reproduction are thus more like those in the higher plants than are those of any of the other groups of Algæ.

The plants of this sub-class are, with few exceptions, very simple in the structure of their vegetative body. Like those of the last group, the predominant form is the gametophyte, the sporophyte being quite rudimentary, and consisting either of the fertilised female gamete, or of a small body resulting from a few divisions of the latter. They show several types of structure. Many are unicellular, and in that case of microscopic dimensions, Others form filaments, each made up of a single row of precisely similar cells, all of which are physiologically alike. A third type is seen in flat plates of cells, only a single cell in thickness; these may be very large and leaf-like, or they may form a very small group, microscopic in size. A group of this kind, in which the cells show no differentiation, or at most a difference between the ordinary cells of the thallus and the reproductive cells, is called a *cœnobium* or colony. Sometimes the cœnobium is spherical, and its cells are all furnished with cilia, giving it powers of locomotion. In a fourth type the thallus is cœnocytic—that is, there are no internal cell-walls formed between the constituent cells, so that the whole plant appears like a single large cell with many nuclei embedded in its protoplasm. The cœnocyte may be a filament, or a somewhat globular body with a branched base (*fig.* 804), or a branched structure showing differentiation into stem, and leaf and root. In some cases of cœnocytic structure the body is divided by transverse walls in several places, so that it may be regarded as composed of a number of cœnocytes. Lastly, the body may be cellular and differentiated into root and shoot, the latter bearing branches and leaves.

In habit the Chlorophyceæ vary but little. They are found in both salt and fresh water. Most forms are free; some are attached to a substratum. A few are endophytic, inhabiting cavities in other plants much as Nostoc does. They present hardly any histological differentiation, with the exception of the Characeæ, where the stem sometimes shows a rather curious structure, and curious reproductive bodies are produced.

The gametophyte may produce both asexual and sexual cells, and may reproduce itself vegetatively by simple division or by the production of gemmæ. The sexual organs are sometimes very simple, any cell of a filament having the power to produce

a number of bi-ciliated gametes, which are liberated by rupture of the cell-wall. These, after a period of activity, conjugate in pairs, the conjugating cells generally originating from two different cells or even two different filaments. The differentiation of sexuality in some of these is very slight, for if they fail to conjugate they can still germinate as if asexual cells. In another group, while apparently any cell of the filament can become a gametangium, the contents are not differentiated into ciliated free-swimming bodies, but the whole of the protoplasm undergoes a kind of rejuvenescence and forms a single gamete. In other forms definite antheridia and oogonia are produced, which furnish antherozoids and oospheres respectively. In each oogonium, as a rule, only a single oosphere is produced, and this is fertilised *in situ* by the entry of an antherozoid into the oogonium (*fig.* 805). This marks a striking advance upon the sexual process in the Phæophyceæ, where the oospheres are set free and fertilised outside in the water. It approaches to the condition in the next group, where more elaborate provision is made to bring the sexual cells together.

Fig. 803.

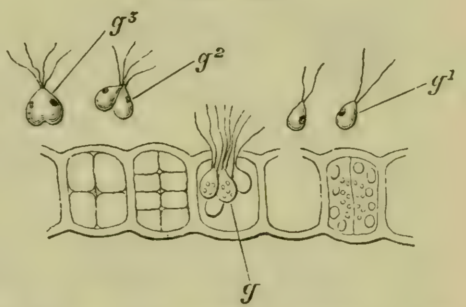


Fig. 803. Part of a filament of *Ulothrix* from which the gametes, g, are escaping. g^1. Free gamete. g^2, g^3. Gametes conjugating.

In the cases of conjugation of the solitary gametes in a gametangium, the fusion of the cells always occurs within one of the cells or an outgrowth from it, the gametes never being set free.

In the latter case parthenogenesis sometimes occurs, a gamete developing into a new filament without any process of conjugation. Such gametes are called *azygospores.*

In one exceptional case, *Sphæroplea*, several oospheres are formed in the oogonium, which is not a specially differentiated cell. Here, too, fertilisation takes place internally, antherozoids finding their way into the cell by an opening in the wall.

Asexual cells are produced by most, but not by all the members of this group. They are generally free-swimming cells, or in some cases cœnocytes, either ciliated all over their surface,

or having a pair of cilia at one end, which is usually pointed, giving them a pear-shaped appearance. They are not produced in specially differentiated gonidangia ; apparently any cell of the thallus can give rise to them.

The sub-class has been very variously subdivided, and at present it is difficult to give a very minute classification. Several types of structure may be briefly described.

PROTOCOCCACEÆ.—These are the simplest of the sub-class; the plants consist of single cells or of colonies of cells united by a common mucilaginous cell-wall. They multiply by cell-division, or by formation of zoospores, or by the conjugation of two free-swimming gametes. In the latter case the zygote represents the sporophyte and gives rise to two zoospores on germination.

FIG. 804.

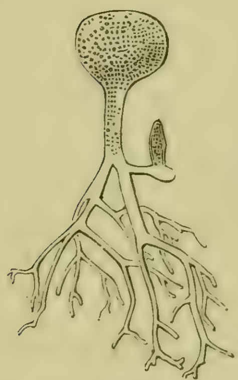


Fig. 804. Branched cell (*Botrydium granulatum*).

VOLVOCCACEÆ.—Of these the most remarkable plant is Volvox itself. It consists of a hollow sphere formed of a single layer of cells, each of which is furnished with a pair of cilia. By the movement of these the plant rotates rapidly and makes its way through the water. Some of the cells of the sphere produce a number of orange-coloured ciliated antherozoids; others represent oogonia, and each gives rise to a single oosphere. The latter is fertilised *in situ* and divides into a number of cells, which become arranged into a hollow sphere like the parent. Certain other cells of the colony, which may be taken to represent gonidia, can divide similarly *in situ*, and produce within their cell-wall a miniature Volvox. Several of these may often be seen in the interior of the hollow sphere of the parent, into which they are discharged from the gonidangial cell. They only escape on the death of the parent. Other genera of this group are *Pandorina* and *Eudorina*; the cœnobium of the former is a solid sphere, that of the latter a hollow one. Pandorina reproduces itself by gametes which are alike, Eudorina by antherozoids and oospheres. The zygote of Pandorina represents the sporophyte and produces zoospores. That of Eudorina is like that of Volvox. Other genera produce colonies or cœnobia which are flattened instead of spherical.

SIPHONEÆ.—These are the most remarkable forms of the group, the thallus consisting of a single cœnocyte, often of very large dimensions, or of a number of cœnocytes attached to each other, forming a filament. The largest members of this family belong to the genus *Caulerpa*, which in many cases simulates the different types of habit exhibited by terrestrial plants. The stem and leaves are nearly always well represented, and the root system is clearly differentiated. The internal cavity of the cœnocyte is crossed by interlacing strands or trabeculæ formed of a modification of cellulose, and springing from the outer wall of the structure. A form of much humbler type, but more familiar to us from its occurrence in fresh-water and in muddy

FIG. 805.

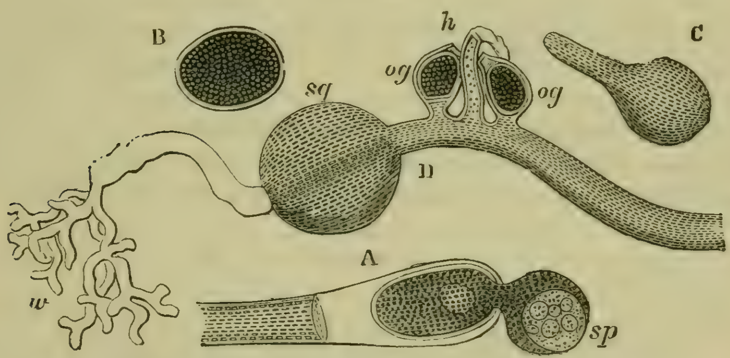


Fig. 805. A. *sp.* Newly formed zoospore or zoogonidium of *Vaucheria sessilis* escaping. B. Zoospore at rest after having lost its cilia. C. First stage of germination. D. Filament of *Vaucheria sessilis* producing oogonia, *og*, *og*, and antheridium, *h*. *w*. Hyaline root-like process, forming a sort of mycelium. *sq*. Zoospore, which by germinating has formed the filament. After Sachs.

places, is *Vaucheria* (*fig.* 805). The plants are filamentous cœnocytes, which branch irregularly or dichotomously. There is but little differentiation, but from some of the filaments curious root-like structures are developed for purposes of attachment. Other forms are *Acetabularia*, where there are stalks crowned by whorls of coherent leaves, and *Botrydium* (*fig.* 804), where a bladder-like head is continued downwards by a slender stalk to a much-branched root, all being a single cœnocyte. Forms composed of several cœnocytes united into a filamentous thallus are shown by the genera *Sphæroplea*, *Cladophora*, &c. The curious genus *Hydrodictyon* is sometimes referred to this group.

The reproductive processes of the group may be sexual or asexual. The sexual cells are usually all alike and are free-swimming ciliated gametes, which conjugate in pairs. Vaucheria is exceptional in producing antheridia and oogonia (*fig.* 805), which are developed in close proximity to each other from the surface of a filament. Each becomes shut off from the rest of the cœnocyte by a cell-wall. The antheridium gives rise to a number of antherozoids which are liberated by the rupture of the apex. The oogonium contains a single oosphere, and when it is mature it opens at the apex, and a drop of mucilage is extruded. An antherozoid enters the oogonium and effects fertilisation. There is no sporophytic form, the zygote germinating to produce a new gametophyte.

FIG. 806.

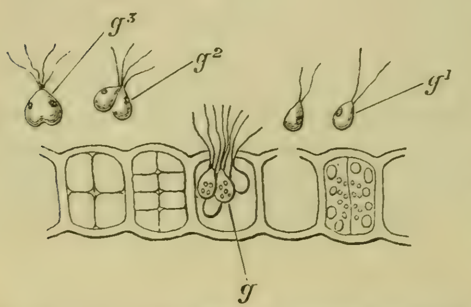


Fig. 806. Part of a filament of *Ulothrix* from which the gametes, g, are escaping. g^1. Free gamete. g^2, g^3. Gametes conjugating.

FIG. 807.

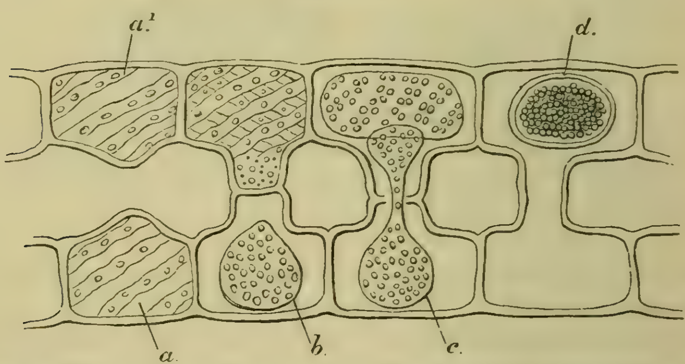


Fig. 807. Conjugation in *Spirogyra*. Two filaments are lying side by side, and from cells opposite to each other protuberances are growing out to meet, a, a^1. Each produces a gamete, b. When the protuberances have met and fused, one gamete passes over and unites with the other, c. d. Adult zygospore.

In *Sphæroplea*, which is composed of several cœnocytes, any segment of the body may become an antheridium or an

oogonium. There is not thus the differentiation of the organs seen in Vaucheria. The antheridia produce a large number of antherozoids, and the oogonia develop several oospheres in each. Fertilisation takes place by the entry of the antherozoids into the oogonia through openings in the walls of the latter, Unlike Vaucheria, this plant shows an alternation of generations, the oospore not producing at once a new Sphæroplea plant, but giving rise to free-swimming zoospores, which form the new filament when they come to rest and germinate. The oospore thus represents the sporophyte.

Asexual reproduction is not common; when it takes place it is brought about by the formation of zoospores. These are generally motile and have a varying number of cilia. In Vaucheria (*fig.* 805), a single zoospore or *zoocœnocyte* is formed at the end of a filament, a portion of which becomes segmented off by a wall. The protoplasm of this portion undergoes rejuvenescence, and becomes ciliated all over, a pair of cilia being placed over each nucleus of the new cœnocyte. It escapes by rupture of the apex of the filament. In some forms the asexual gonidia are non-motile.

Confervoideæ.—The forms included in this group are either unicellular, filamentous, or membranous; the filaments are sometimes branched, sometimes not, the membranous ones sometimes form flat plates, sometimes hollow or tubular expansions. The growth of the filaments is generally intercalary. They are always composed of cells and not of cœnocytes.

The processes of reproduction are both sexual and asexual. The origination of sexuality can be traced in some members of the group. In *Ulothrix*, which is a filamentous multicellular form, the contents of certain cells of the filament give rise to a large number of free-swimming ciliated cells, which indicate in their behaviour the beginning of sexual differentiation. They often conjugate in pairs (*fig.* 806), forming zygospores and thus indicating that they are essentially gametes. If they do not succeed in conjugating, they still can germinate; a fact which shows that they are much akin to ordinary zoogonidia.

A further evolution of sexuality is found in the *Zygnemiæ*, to which *Spirogyra* belongs. Any cell of the filaments of the plant can become a gametangium. In the process of conjugation two filaments come to lie parallel with each other, and from the middle of each cell a lateral process grows out towards the other filament (*fig.* 807, *a a*). The opposite processes join and their walls fuse, forming a tube which stretches across between the

two gametangia. The protoplasm of each undergoes rejuvenescence to form the gamete, and one of them passes over into or through the tube and fuses with the other gamete, which either enters the tube to meet the first or remains in its gametangium, where it is joined by the other. The first condition is found in *Zygogonium*, and as there is no difference between the gametes taking part, we cannot speak of difference of sex. In *Spirogyra* (*fig.* 807) the cell which passes over through the tube begins to be differentiated slightly sooner than the other and may be held to be the male one.

FIG. 808.

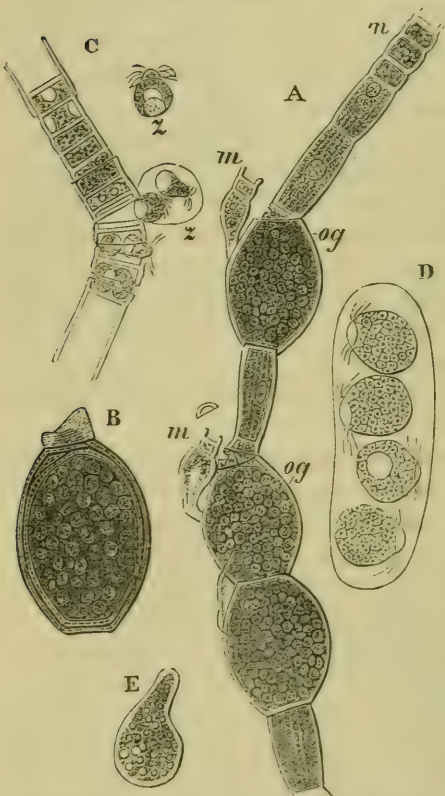


Fig. 808. A. Middle part of a sexual filament of *Œdogonium ciliatum*. *og*, *og*. Oogonia fertilised by the dwarf male plants, *m*, *m*, developed from zoospores formed in the cells, *n* (antheridium), at the upper part of the filament. B. Ripe oospore. C. Piece of male filament of a species of *Œdogonium*, with production of antherozoids, *z*, *z*. D. The four zoospores resulting from an oospore. E. Zoospore at rest. After Pringsheim.

In *Œdogonium* sexuality is completely established, antherozoids and oospheres being produced. In some cases the whole contents of the antheridium forms a single antherozoid, which is ciliated.

Unicellular forms occur in this group in the family of the *Desmids*. These are cells of bright-green colour and usually peculiar shape. Their colouring matter is collected into curiously formed chloroplasts, which may occur as bands stretching the whole length of the cell, and having pyrenoids embedded in them. They multiply chiefly by fission, as do the Diatoms, to which group they present certain resemblances. Occasionally two individuals conjugate

to form a zygospore, which germinates and produces two new plants.

The Zygnemiæ are, like the Desmids, furnished with peculiar chloroplastids. In *Spirogyra* these form a spiral band which winds round the cell; in *Zygnema* they form two stellate plates; other forms occur in other genera.

Œdogonium (*figs.* 808, 809) is noteworthy among the group on account of certain peculiarities of its reproduction. The ordinary filament produces a number of oogonia along its length, the cells swelling and becoming ovoid. Each produces a single oosphere. The antheridia may be on the same filament as the oogonia or on a different one. A cell of such filament divides transversely several times, and each cell so formed becomes an antheridium, giving rise either to a single antherozoid or dividing into two to form two mother-cells, each of which produces one. The oogonium admits the antherozoid usually by a perforation of the wall. Sometimes no antheridia are formed directly on the parent filament. Instead, special cells produced in the same way as antheridia set free their contents in the form of a ciliated cell known as an *androspore*. It is much like an antherozoid, but differs from the latter in its behaviour. It becomes attached to the wall of an oogonium and germinates, forming a very small plant, of three or four cells, known as a *dwarf male*, the upper cells of which are antheridia, and produce each a single antherozoid. When the oosphere is fertilised it clothes itself by a cell-wall, and the oospore so formed in due time germinates and produces four zoospores (fig. 808 D). It thus represents the sporophyte.

FIG. 809.

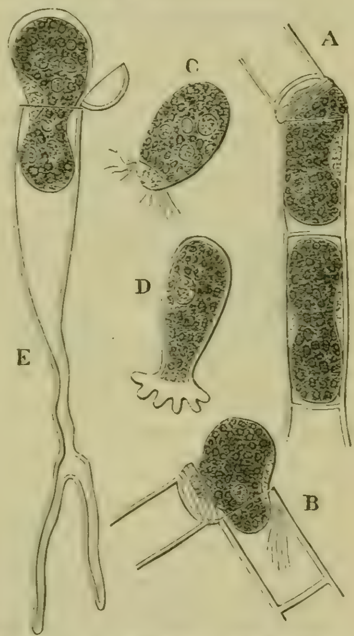


Fig. 809. A, B. Escape of the zoogonidia of an *Œdogonium*. C. One in free motion. D. The same after it has become fixed, and has formed the attaching disc. E. Escape of the whole protoplasm of a germ-plant of *Œdogonium* in the form of a zoogonidium. After Pringsheim.

Coleochæte is a form which in some respects approaches the red seaweeds. Its thallus is composed of much-branched filaments forming a tufted mass which grows apically or marginally. The cells in some cases bear peculiar sheathing hairs. The plant bears antheridia and oogonia, each of the latter bearing a trichogyne except in a few species. The antherozoid enters the oogonium by an opening in the trichogyne and fertilises the oosphere.

The result of the fusion is the production of a more elaborate sporophyte than in any other member of the Chlorophyceæ. The oosphere secretes a cell-wall round it, and the oogonium in which it lies becomes surrounded by a kind of cellular covering derived from the cells of the thallus near it. It thus forms a kind of fructification which becomes detached from the parent. Later the oospore germinates, rupturing its coating; it only produces a few cells, each of which gives rise to a single zoospore.

Fig. 810.

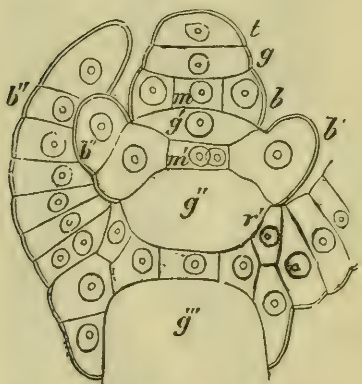


Fig. 810. Longitudinal section through the apical region of three primary shoots of *Chara fragilis*. *t*. Apical cell, in which segments are formed by septa, each segment being further divided by a curved septum into a lower cell not further divisible, which develops into an internode, *g*, *g′*, *g″*, *g‴*, and an upper cell which produces a node, *m*, *m′*, and the leaves, *b*, *b′*, *b″*, *b″*, which also undergo segmentation. After Sachs.

The asexual reproductive cells produced by the Confervoideæ are zoogonidia or zoospores, as they are produced on the gametophyte or the sporophyte respectively. They are variously ciliated, and always on germination produce a gametophyte (*fig.* 809). The process of asexual reproduction is not found in the Desmids nor in the Zygnemiæ.

The last type of structure is found in the CHARACEÆ, represented most familiarly by the two genera *Chara* and *Nitella*. In some respects these approach nearest in structure to the Bryophytes; among the Chlorophyceæ they are distinguished by their relatively great degree of both morphological and anatomical differentiation and by the complex structure of their reproductive organs.

Chara exhibits a long slender stem, bearing whorls of leaves

and branches, and consequently divided into nodes and internodes. The branches are developed in the axils of the leaves. The lower portion of the stem gives rise to a number of adventitious roots, which are filamentous and multicellular.

The growth of root, stem and leaf is apical; in the stem and branches it is carried on by an apical cell.

The nodes and internodes differ in structure; in the latter the central core is formed by a single very elongated cell, which in the older parts contains several nuclei. It is not a cœnocyte, the nuclei being derived from the fragmentation of the original nucleus. This cell is covered in by a cortex consisting of a number of rows of cells which spring from the nodes above and below and accompany the internodal cell in its elongation. The nodes are made up of a number of small cells, from the external ones of which the branches and leaves arise.

The growing point of the stem of Chara is seen in *fig.* 810. When it divides it cuts off a segment by a transverse wall; this cell is again divided similarly into two, of which the upper becomes a nodal and the lower an internodal cell. The nodal cell divides by vertical walls, while the internodal one only elongates. The peripheral ones grow upwards and downwards to help to form the cortex of the internode above and below it. The apical cell of the leaf is similar to that of the stem, but it only keeps its activity for a short time. The apical cell of the root is not differentiated.

The reproductive organs are antheridia and oogonia, and are produced at the nodes of the stem. The antheridium is a shortly-stalked globular body, sometimes called a *globule*. Its case consists of eight cells with curious thickenings upon their surfaces. The top cell of the stalk projects into the interior of the antheridium between the bases of the lower cells of the case. Each of the eight wall-cells, known as *shields*, bears a long cell projecting into the interior, which is termed a *manubrium*; this is crowned by a smaller globular cell, the *capitulum*, and this in turn gives rise to six *secondary capitula*. Springing from each of these are two long filaments, divided into a large number of cells, each of which gives rise to a single antherozoid. The antherozoids are twisted masses of protoplasm, bearing two cilia at their anterior ends.

The oogonium is also stalked, the central cell being surrounded by filaments which arising beneath it from the node coil spirally round it. Each filament cuts off a small cell at its

apex, so that the oogonium is covered in by a kind of neck or crown consisting of small cells. There are usually five of these. When the oogonium is mature these cells separate from each

Fig. 811.

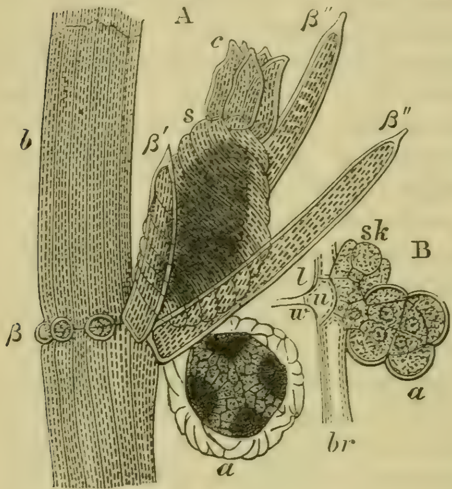


Fig. 812.

Fig. 813.

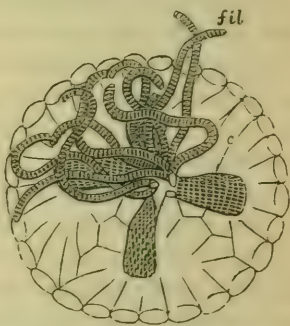


Fig. 814.

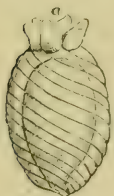


Fig. 815.

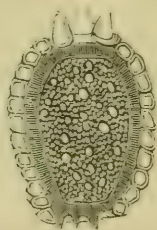


Fig. 811. A. Portion of the axis of *Chara fragilis*. *s*. Nucule or oogonium. *a*. Globule or antheridium. *b*. Internode. *c*. Crown or corona of nucule. β. Abortive leaves. β', β'', β''. Sterile leaflets. B. *sk*. Nucule, and *a*, globule, both in an early stage of development. *w*. Nodal cell of leaf. *u*. Union cell between it and basal node of globule. *l*. Cavity of internode of leaf. *br*. Cells of leaf covered with cortex. After Sachs.——*Fig.* 812. A portion of a filament, *fil*, of *fig.* 813, in the cells of which the antherozoids are developed; with a 2-ciliated *antherozoid* by its side.——*Fig.* 813. A globule cut in half to show the oblong cells or manubria, *c*, and the septate filaments, *fil*. After Henfrey.——*Fig.* 814. Nucule or archegonium of *Chara*. *a*. Apices of the spirally wound cells.——*Fig.* 815. Vertical section of a nucule.

other, leaving a small channel through which the antherozoid can make its way.

The oosphere is solitary in the oogonium, though as it becomes ready for fertilisation it cuts off one or two small cells

from near its base. These cells are separated from it by cell-walls, but the oosphere itself remains naked.

The oogonium does not open, but the antherozoid makes its way through the cell-wall, which undergoes a sort of mucilaginous degeneration. The fertilised oosphere after fusion with it becomes an oospore with a very thick wall.

FIG. 816.

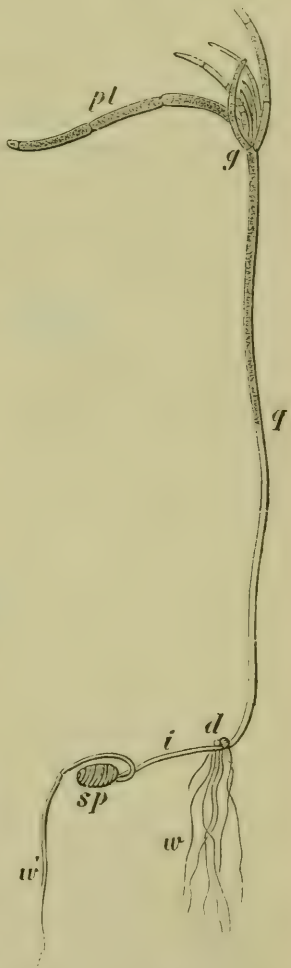


Fig. 816. Pro-embryo of *Chara fragilis*. *sp*. Germinating spore. *i*, *d*, *q*, *pl*. The pro-embryo. At *d* are the rhizoids, *w*. *w'*. Primary root. *g*. First leaves of the second generation, or *Chara* proper. After Pringsheim.

The germination of the oospore is peculiar; a transverse wall is formed near the apex and a small cell is so separated from the rest. The latter part of the oospore takes no part in the further development, but remains as a store of nutriment for the young embryo. The small cell divides into two, and from one of these the new shoot is developed, the primary root arising from the other. A small *pro-embryo* is thus produced which bears a single whorl of leaves and a few adventitious roots. The Chara plant arises as a bud upon this, its apical cell being differentiated among the whorl of leaves (*fig*. 816, *g*).

In the genus Nitella the stem is much more slender than in Chara, and it is not furnished with a cortex.

There are no asexual cells produced, but vegetative propagation is sometimes brought about. Certain branches of peculiar form may become detached from the parent and grow into new plants; or gemmæ may be developed upon the underground nodes.

Not producing any asexual cells, Chara does not exhibit any alternation of generations. The plant is the gametophyte.

CLASS II.—FUNGI.

This class of Thallophytes differs from the preceding one especially by the absence of chlorophyll from the tissues of the plants which it comprises. In other respects there is a great similarity between the two groups. The absence of chlorophyll, however, makes such a material difference to the mode of nutrition, and leads ultimately to such great differences in degree of development, that they are properly separated into two distinct classes. The fungi cannot assimilate the CO_2 of the atmosphere, and are therefore compelled to obtain their carbonaceous food from somewhat complex compounds, which have, however, a fairly wide distribution. Some fungi obtain them from other living organisms, both animals and vegetables, on which they prey, their tissues entering into the living substance of their hosts and absorbing therefrom the food-stuffs they need. These are called *parasites*. Others grow upon decaying organic matter, either in the soil or elsewhere; these are known as *saprophytes*. Yet a third class exists, whose members live in intimate relationship with living green plants, the two forming together a complex organism, partly chlorophyllaceous, partly fungal, the two constituents playing each its own part in the nutrition of the whole. Such a mode of life is called *symbiosis*; it differs from parasitism in that the fungus does not in any way injure the green plant with which it is in such close relationship. The best examples of symbiosis may be found in the next class, the Lichens, where an alga and a fungus live together. In this it is illustrated by the micorhiza found on the roots of many of our forest trees.

In their life history the fungi show an alternation of generations, but not at all a regular one. Many species have both gametophyte and sporophyte phases, but these rarely if ever alternate with constancy. The gametophyte is always the larger and most important form, the sporophyte being sometimes represented only by the oospore or zygospore, sometimes by a small *promycelium* developed from it, sometimes by a kind of fructification recalling the cystocarp of the red Algæ. The gametophyte usually bears spores or gonidia in addition to the gametes; indeed

many gametophytes are only potential ones, usually producing gonidia alone. Many generations of these may occur in succession before an actual one with sexual organs is formed. Hence we get often, as in the Algæ, in the life history an alternation, generally very irregular, of potential with actual gametophytes, in addition to the alternation of sporophyte with gametophyte, which is also very irregular. The former has been called *homologous*, the latter *antithetic* alternation.

Again, some of the gametophytes have lost the power of

FIG. 817.

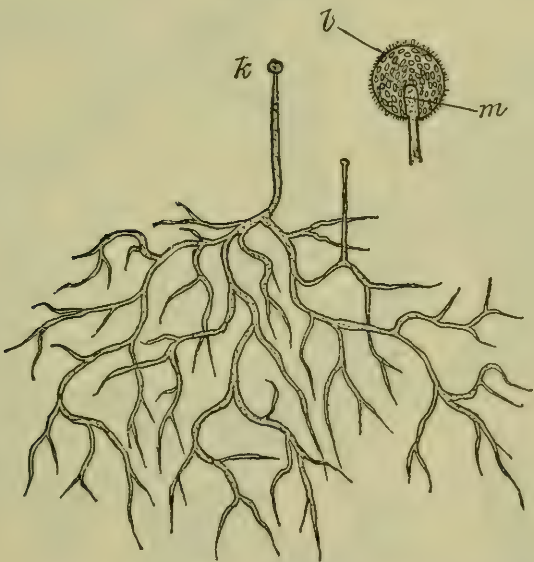


Fig. 817. Cœnocyte of *Mucor Mucedo*, bearing a sporangium or gonidangium, *k*. This is more highly magnified in the fig. to the right. *m*. Columella. *l*. Gonidia or spores.

producing sexual cells at all, probably in consequence of the degeneration of structure that has accompanied the parasitic or saphrophytic modes of nutrition. They thus never produce any reproductive cells but gonidia, and can only be distinguished as gametophytes by a careful study of their homologies.

Polymorphy is very wide-spread among the Fungi. As we have seen, the plant body is in most cases the gametophyte. It may be unicellular, consisting of separate cells of various shapes, rounded, oval, or irregular. It may be a cœnocyte (*fig.* 817), when the appearance it presents is that of a number of white

interlacing filaments, or *hyphæ*, with no separating transverse walls, but with many nuclei embedded in the protoplasm which lines them. This network of hyphæ, which is characteristic of most fungi, is known as the *mycelium*. Often the mycelium is septated into segments, each of which is a small cœnocyte. In one group, the Myxomycetes, the plant body is a *plasmodium* (*fig.* 818), consisting of an aggregation of cells which possess no cell-walls, but are capable of amœboid movements. The plasmodium is of course a form of cœnocyte.

FIG. 818.

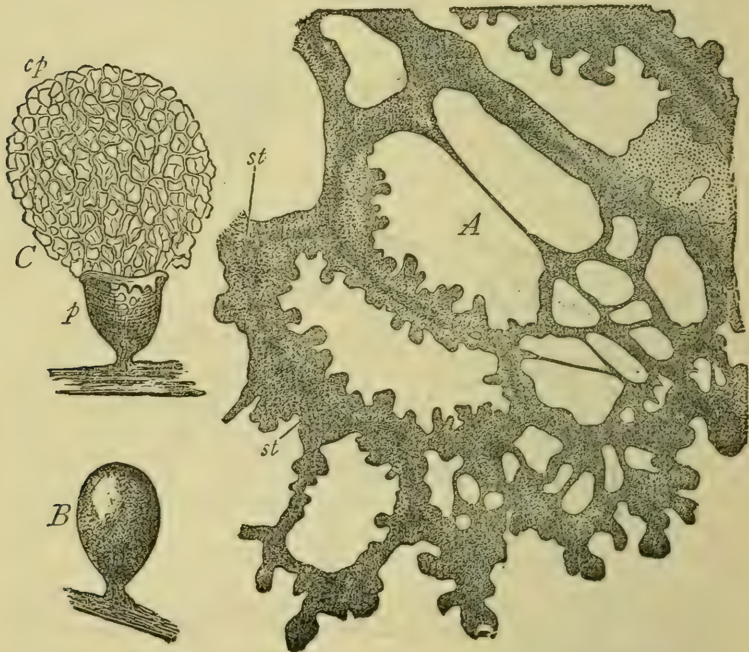


Fig. 818. A. Plasmodium of a Myxomycete (×300). B. A fructification still closed. C. After rupture of the wall *p*, and extension of the capillitium. After De Bary ×20.

The degree of differentiation which is shown by the plant body varies a good deal. Some are always single cells, others by division of these form strings or chains of cells; others form the mycelia already noticed, and in many cases the hyphæ of these, combining in various ways as they grow, produce large masses of tissue.

In nearly all cases but the first two, the body can be seen to be composed of parts which may be called root and shoot. In

many the former is much the greater in extent and forms the larger part of the mycelium, being buried in the substratum on which the fungus is growing. In such cases the shoot is composed of a few hyphæ, bearing the reproductive organs. In other cases the shoot is large and bulky. In some parasitic forms the root hyphæ take the form of *haustoria*, or sucking organs, which penetrate into the cells of the host plant (*fig.* 819), the rest of the mycelium being found only between the latter. Sometimes, instead of forming a feltwork of mycelium, the root hyphæ are gathered into bundles. The shoot, especially when bulky, is of curious and varied form and never bears anything that can be called a leaf.

FIG. 819.

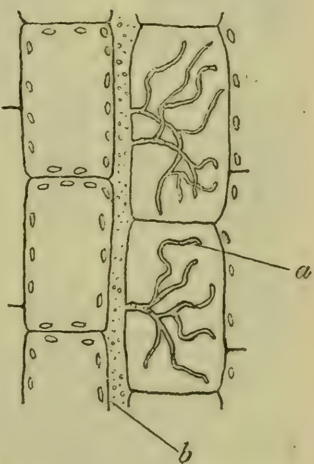


Fig. 819. Four cells of potato plant, infested with Phytophthora. *b.* Hypha running between the cells and sending haustoria, *a*, into their interior.

Corresponding with this rudimentary morphological differentiation, the anatomical structure is very simple. The long chains of cells are produced by ordinary cell-division; the elongated hyphæ grow at their apices; in the masses of tissue of the more bulky forms a transverse section shows the appearance of a kind of parenchymatous tissue. It is not a true parenchyma, however, being composed of hyphæ which run side by side, cohering together. The outer layers of such a mass form a kind of cortex, which is more compact than the inner parts. Occasionally some of the hyphæ are modified to form a system of laticiferous tissue, and a kind of gland is formed in some other species. These forms are found generally in the most complex group, the Basidiomycetes.

The cell-walls of the fungi are composed of a modification of cellulose, characterised by not turning blue when treated with iodine and sulphuric acid. This modification, known as *fungus cellulose*, has recently been shown to resemble in some respects the *chitin* found in some animal organisms.

The reproductive structures found in the fungi are very varied. Sexual reproduction is represented in several of the groups, but in others it is unknown, the gametophytes being always potential and not actual. In many a somewhat elaborate

sexual apparatus is formed, but it is doubtful how far actual fusion of the gametes takes place.

The gametes may be alike. In this case they are never set free from the gametangia, but the walls of the latter coalesce and fusion takes place inside the structure so formed, a zygospore being the result (*fig.* 820). These isogamous fungi form the group of the Zygomycetes.

Fig. 820.

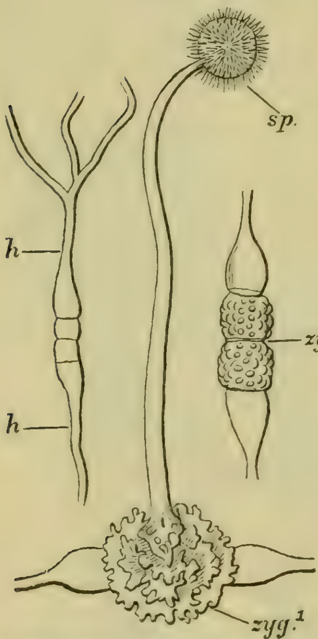


Fig. 820. Conjugation in *Mucor Mucedo*. *h*. Two hyphæ which have come into contact at their apices, and each has cut off from itself a cell. *zyg*. Zygospore resulting from the fusion of these cells. *zyg*[1]. Adult zygospore after germination. *p*. Promycelium bearing a sporangium *sp*.

In other cases both male and female gametes are found. The female is usually an oosphere, contained either singly or in numbers inside a structure that may be called an oogonium (*fig.* 821). In this case the male usually consists of a mass of naked protoplasm, which occurs in a special branch of one of the hyphæ, in close proximity to the oogonium. This branch is known as a *pollinodium* (*fig.* 821, *an*). In another section the male gametes are differentiated and are set free. They are small rounded cells, clothed with a cell-wall, and known as *spermatia*. They are produced by abstriction from the apex of a special filament, the *sterigma*, a number of these being developed in a special receptacle, the *spermogonium*. The female organ, which is known as an *archicarp* (*fig.* 783), contains no differentiated female cell, and corresponds to the procarpium of the Rhodophyceæ. This sometimes has a *trichogyne*, as in the latter group.

In some forms which bear an archicarp the male cell is not differentiated either, but is much like the gamete of the group last mentioned, being produced by a hypha close to the archicarp. The product of fertilisation in the last two cases is known as an *ascocarp*, and is the sporophyte of the plant.

The spores or gonidia of fungi are borne in great numbers, and receive different names according to the organs in or on which

they are produced. The sporophyte rarely occurring, it follows that they generally arise upon the gametophyte. In most cases they are small rounded bodies, each with its cell-wall. They may be produced singly in a cell, as in the Schizomycetes, or in groups of four or eight, as in the Ascomycetes. In most Phycomycetes they are produced in great numbers in globular or club-shaped sporangia or gonidangia (*fig.* 823) borne upon special aerial hyphæ, termed *gonidiophores*. In other cases the

FIG. 821.

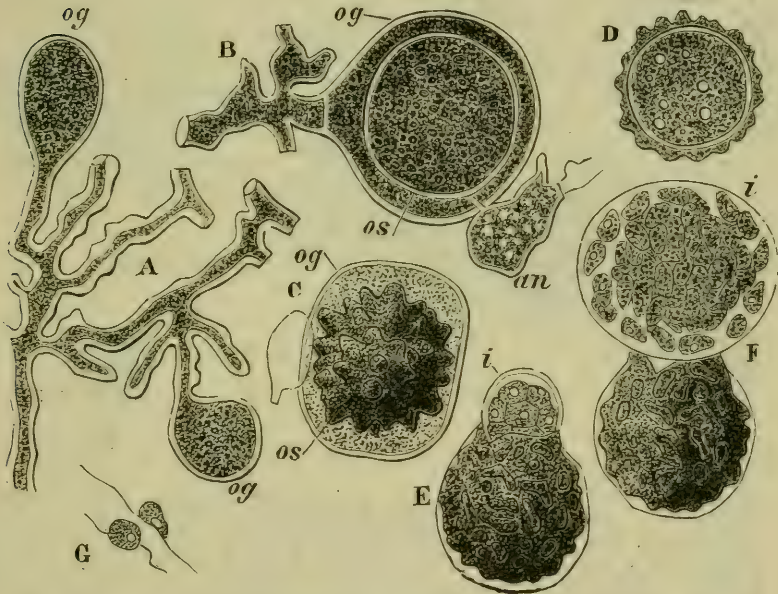


Fig. 821. A. Branched mycelium of *Cystopus* with young oogonia, *og*, *og*. B. Portion of mycelium bearing oogonium, *og*, with the oosphere, *os*; and antheridium or pollinodium, *an*. C. Mature oogonium, with *os*, the oospore. D. Mature oospore. E, F. Formation of swarm-spores or zoospores, G, from the oospores. *i*, *i*. Protruded endospore. After De Bary.

spores are never in a sporangium, but are produced from special hyphæ by a process of abstriction or budding, leading to the formation of strings of them, called *stylogonidia* (*fig.* 824). Usually each spore ultimately becomes free. In one group, the Uredineæ, they remain together, in number two or more (*fig.* 825), each of which can germinate while associated with the others. These are sometimes looked upon as compound spores, though each one is actually independent. This form is known as a *teleutospore*. There is some doubt as to whether the

bodies described above as spermatia are not a form of the stylogonidia, and not sexual cells at all. In some cases they have been found to be capable of germination, producing a mycelium without any sexual fusion.

In a few families, such as the Saprolegnias, the spores are not clothed with a cell-wall, but are ciliated free-swimming bodies. They are produced in great numbers inside special terminal sporangia (*fig.* 826).

Fig. 822.

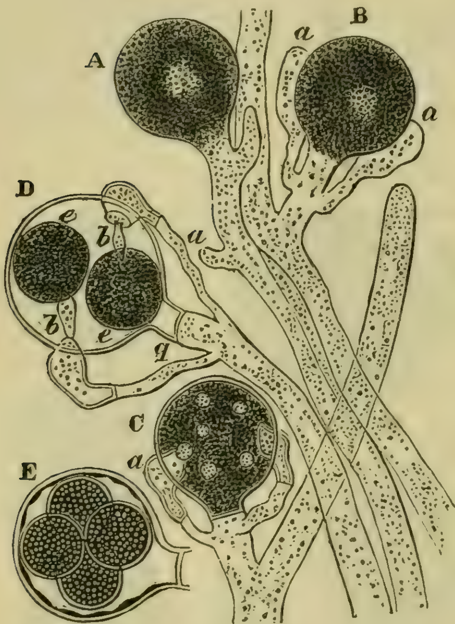


Fig. 823.

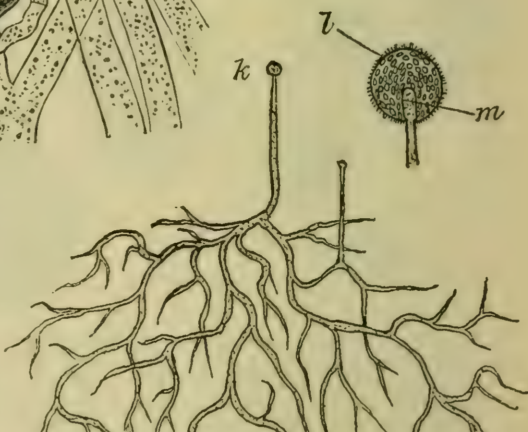


Fig. 822. Oogonia and antheridia of *Achlya lignicola*. The letters A to E indicate the course of development. The protoplasm of a cell or branch of a cell collects into a globular form A, B, and by the formation of a septum, D *q*, becomes an independent cell (the oogonium). The protoplasm then breaks up into two or more parts, D, *e*, *e* (oospheres), which quickly become spherical, as seen in D, secrete a cell-wall E, and become oospores. After Sachs.——*Fig.* 823. Cœnocyte of *Mucor Mucedo* bearing a sporangium or gonidangium. *k*. This is more highly magnified in the fig. to the right. *m*. Columella. *l*. Gonidia or spores.

The sporangia or gonidangia may be produced singly or in groups. In the latter case the gonidiophores which bear them may be collected into special receptacles which are known as *pycnidia*.

Besides these sexual and asexual modes of reproduction, vegetative reproduction very commonly occurs. In forms such as Bacteria and yeast it is much the most general method, and consists only of ordinary cell-divisions, the daughter cells at once separating from the one which gives rise to them. Sometimes in yeast this separation does not at once take place, with the result that chains of cells are produced (*fig.* 827).

Fig. 824.

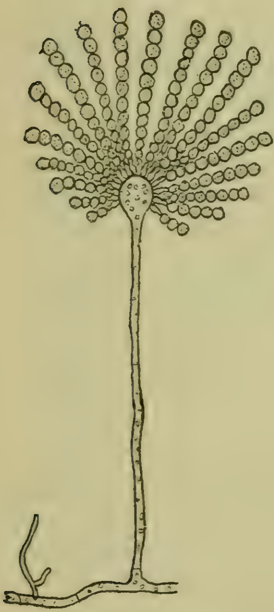


Fig. 825.

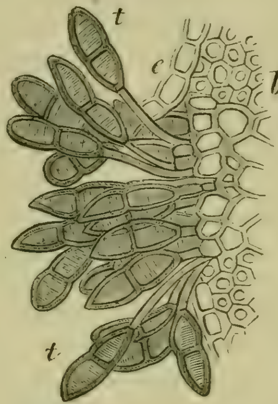


Fig. 826.

Fig. 827.

Fig. 824. Stylogonidia or stylospores of Eurotium, formed by repeated abstriction from the basal cell. After Dodel-Port.——*Fig.* 825. Teleutospores of *Puccinia graminis* bursting through epidermis of straw. After Dobel-Port.——*Fig.* 826. Two gonidangia of Achlya. A. Closed. B. Ruptured, and allowing the zoogonidia *a* to escape. *b.* Mother cells of the latter after escape of *e*, the zoogonidia, from them.——*Fig.* 827. Two yeast cells budding.

In other cases a hypha divides by the formation of transverse septa into a number of cells, each of which becomes rounded off, and the chain breaks up into single cells which are capable of immediate germination. They are often called *oidium* cells. More complex forms are the bodies known as *sclerotia*, which are composed of a mass of hyphæ closely felted together and covered by a pseudo-cortex. These separate from the mycelium which

gives rise to them, and remain dormant for a longer or shorter period, ultimately putting out hyphæ like those of the original mycelium.

The fungi have been classified in various ways by different writers. The system which is now usually adopted divides them into six groups as under :—

1. Schizomycetes, including those bodies commonly spoken of as microbes, or bacteria. They are sometimes unicellular, sometimes filamentous and composed of chains of cells. They have no sexual reproduction.
2. Myxomycetes. The body of the fungus is a plasmodium or aggregation of amœboid cells with no cell-wall. They produce spores, but have no sexual reproduction.
3. Phycomycetes. These have usually a mycelium composed of a much-branched cœnocyte with no septa. They are often erroneously described as unicellular, a condition which, however, does occur in some cases. They reproduce sexually and asexually, zoospores and ordinary non-motile spores occurring in different orders. The sexual reproduction is a process of conjugation or fertilisation, leading to the recognition of two groups accordingly, the Zygomycetes and the Oomycetes. In the former the zygote is a zygospore, in the latter an oospore.
4. Ascomycetes. The cœnocytic structure is found in this group also, but the whole plant is usually not a single cœnocyte, but incompletely septated, forming a number of them. The female organ is a carpogonium, containing no differentiated gamete ; the sporophyte is inconspicuous, but represented by the so-called fructification.
5. Æcidiomycetes. The mycelium has the same structure as in the last group. There is no sexual reproduction known. Several kinds of spore are borne. There is an elaborate structure produced called an *æcidium*, which may possibly represent the sporophyte, but the homologies are doubtful.
6. Basidiomycetes. The mycelium is much like those of the last two groups. No sexual reproduction is known. The mycelium produces a massive structure, on certain parts of which the spores are produced by abstriction from special cells, known as *basidia*.

Sub-Class I.—Schizomycetes.

The members of this group are very small, and almost structureless. The unicellular forms have various shapes, some being

spherical (Micrococcus), some more elongated or rod-shaped (Bacterium), some forming a spiral (Spirillum). The multicellular forms are filaments, branched or unbranched, or small masses of cells. They are extremely polymorphic, one organism passing through several forms in its life history. Some are furnished with cilia, by which they move rapidly in the medium in which they live (*fig.* 828).

The cells are of a very simple structure, consisting of a cell-wall enveloping a mass of protoplasm. In this is found a body capable of staining more deeply than the rest of the cell-contents, and hence thought to be a nucleus. The protoplasm often contains deeply staining granules, sometimes regularly disposed round the cell. The true nature of the staining

Fig. 828.

Fig. 828.
1. Sarcinæ.
2. Bacteria.
3. Spirilla.
4. Spirillum, showing flagellæ.
5., 6., 7. Micrococci in strings, singly and in groups. After Cohn and Sachs. (Very highly magnified.)

material is, however, not yet accurately ascertained. Many of these cells contain various pigments.

In the course of their life history, most of the Schizomycetes become embedded in a jelly-like substance which holds great numbers of them together. This is known as the *zooglœa* stage. The zooglœa may form a membrane or scum on the surface of the liquid in which the organism is living, or may occur in the shape of masses of various forms.

The reproductive processes are either vegetative or asexual. In the former case the multiplication takes place with enormous rapidity by ordinary cell-division. In the second case spores are formed, one in a cell, by a process of rejuvenescence. A filament may thus give rise to a chain of spores, which ultimately become separate by the degeneration of the original cell-

wall. The spores have their own proper coats, which are much thicker and more resistent than the ordinary cell-wall. The zooglœa stage is generally the one in which the plant forms its spores.

It is to these organisms chiefly that the processes of fermentation and putrefaction are due, though other fungi take part in similar phenomena.

Sub-Class II.—Myxomycetes.

This curious group is distinguished by the fact that, except at a particular time in its life, it possesses no cell-walls. Originating

Fig. 829.

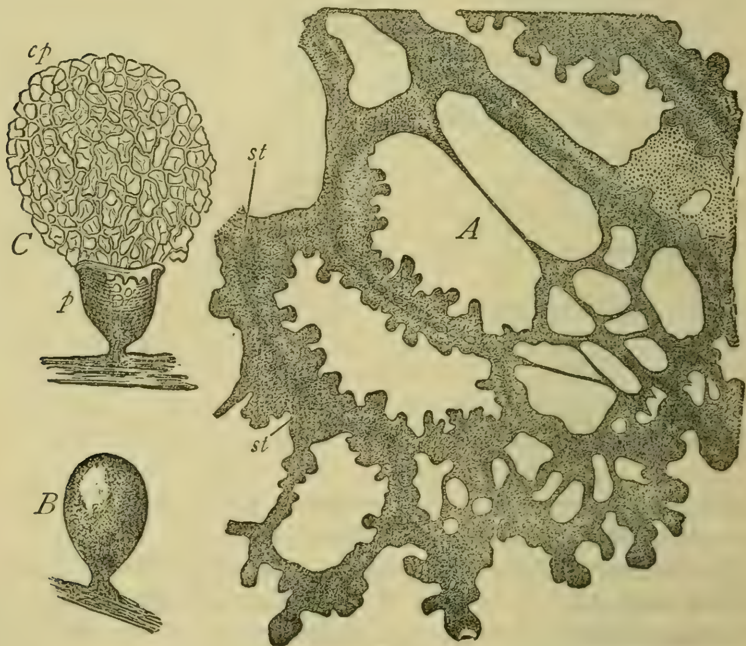


Fig. 829. A. Plasmodium of a Myxomycete ($\times 300$). B. A fructification still closed. C. After rupture of the wall, *p*, and extrusion of the capillitium. After De Bary $\times 20$.

from spores, the contents of the spore escape as a naked mass of protoplasm, which in some forms is capable of active movement by means of a cilium, and in others can only creep about slowly, by means of protrusions which it can put out from its substance. These are called *pseudopodia*. In the first case, the freely motile body passes over later into this stage, so that

the myxomycete is at some time characterised by this behaviour which recalls the condition of the form of animal known as the Amœba. While the separate masses are still motile they can multiply by cell-division, which has been ascertained to be preceded by karyokinesis. Ultimately the amœboid masses collect into a *plasmodium*, without fusion of the nuclei, so forming a kind of cœnocyte (*fig.* 829, A). Like the constituent cells, the plasmodium can creep about by means of pseudopodia. A familiar example of this fungus is the so-called 'flowers of tan' (*Ethalium*), which is found in the form of jelly-like lumps in tan yards.

The plasmodium in time comes to rest, and gives rise to one or more sporangia. In the latter case it divides into as many pieces as sporangia. The whole of the mass shrinks up into a rounded body which shows differentiation into a hardened outer portion or wall, and an inner mass which gives rise to spores. The substance of the inner portion produces a peculiar protoplasmic network of filaments, the *capillitium* (*fig.* 829, C), among which are formed the spores, these being furnished with a cell-wall which each secretes independently. Sometimes the sporangium is stalked, sometimes not; occasionally a protrusion of the stalk into the sporangium forms a kind of *columella*. The spores are, after a time, liberated, or scattered by the elastic capillitium, and give rise to the amœboid masses already described.

Sub-Class III.—Phycomycetes.

In this group we have the only undoubted cases of sexual reproduction, which may take the form of conjugation, or fertilisation, thus giving rise to two sections, the *Zygomycetes* and the *Oomycetes*. In both groups the mycelium is unseptate, or incompletely septate, being a cœnocyte.

Zygomycetes.—The form most generally known in this group is the common mould, *Mucor Mucedo*, found generally on dung and other decaying organic matter. The spore gives rise to a copiously branched mycelium, which ramifies very freely in the substratum. When well established it throws up aerial branches which terminate in globular heads or gonidangia. A septum is formed close to the apex of the hypha, cutting off a small head which grows and becomes globular. The lower cell grows also, and projects into the swollen portion, forming a columella (*fig.* 823, *m*). The contents of the terminal cell break up into a

number of spores or gonidia. The wall of the gonidangium usually becomes impregnated with crystals of oxalate of calcium.

The sexual reproduction is carried out by means of undifferentiated gametes. Two hyphæ from the vegetative part of the mycelium approach each other, and a septum cuts off from each a small cell, which is the gametangium. The two gametangia come into contact, and the walls between them are absorbed, so that the gametes, which are the undifferentiated protoplasm of the gametangia, fuse together, forming a zygospore (*fig.* 830). This grows into a globular body which secretes round itself a thick cuticularised wall. After a period of rest this body germinates, pulling out a small mycelium, called a *promycelium*, which gives rise to a sporangium (*fig.* 830, *sp*) much like that borne upon the ordinary fungus body. This promycelium represents the sporophyte, the ordinary form being the gametophyte. In some species of Mucor the gametangia are single and conjugation does not take place; the body produced parthenogenetically by such a gametangium is called an *azygospore*.

FIG. 830.

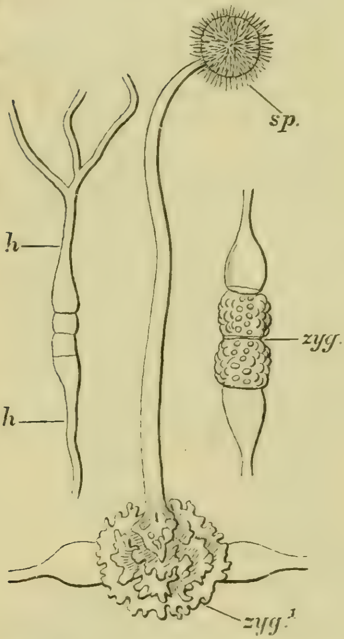


Fig. 830. Conjugation in *Mucor Mucedo*. *h*. Two hyphæ which have come into contact at their apices, and each has cut off from itself a cell. *zyg*. Zygospore resulting from the fusion of these cells. *zyg*[1]. Adult zygospore after germination. *p*. Promycelium bearing a sporangium, *sp*.

Under unfavourable conditions of nutrition, as when the hyphæ are immersed in liquid, the mycelium of Mucor may divide up into a number of oidium-like cells much like yeast cells. This is called the *Torula* form; it is capable, like yeast, of setting up alcoholic fermentation in a sugary fluid. Sometimes the separate cells are large and thick-walled, when they are known as *Chlamydospores*.

There are two other groups in this sub-class, the Chytridiaceæ and the Entomophthoraceæ. The former produce zoospores in ordinary sporangia or gonidangia, and in special thick-walled

sporangia, after a period of rest. Zygospores are also formed, but the differentiation of the sexual organs is not so complete as in the Mucorinæ. The Entomophthoraceæ are parasitic on insects. They differ from Mucor chiefly in the mycelium being incompletely septate, being thus composed of a number of cœnocytes, instead of a single one.

Oomycetes.—The chief members of this group are the Peronosporeæ and the Saprolegniæ. The former are chiefly parasitic, causing many of the diseases of Phanerogamic plants, though saprophytic forms occur. A typical instance of them is the fungus *Phytophthora infestans*, which causes the potato disease. The hyphæ ramify usually between the cells of the plants, sending haustoria into their interior and so absorbing their nutritive juices (*fig.* 831). The mycelium sends out hyphæ through the stomata of the leaves, which bear gonidangia at their apices. In Phytophthora these hyphæ are branched and bear several gonidangia; in Peronospora each bears a single one. In some cases the gonidangium gives rise to zoogonidia, in others it behaves like a gonidium and puts out a hypha directly.

Fig. 831.

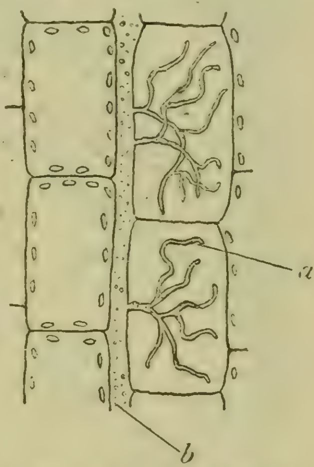


Fig. 831. Four cells of potato plant, infested with Phytophthora. *b*. Hypha running between the cells and sending haustoria, *a*, into their interior.

The sexual reproduction of this group is seen best in such forms as *Pythium* and *Cystopus*. A hypha cuts off a cell at its apex, which becomes swollen and rounded and forms an oogonium. Its contents give rise to a single oosphere, part of the protoplasm only being concerned in its formation while the rest forms a peripheral layer, the *periplasm*. The male organ or *pollinodium* is produced in a similar manner from a hypha, which sometimes springs off as a lateral branch from that which bears the oogonium and sometimes from an adjacent one. The pollinodium becomes closely applied to the oogonium and penetrates its wall by means of a delicate tube which serves to conduct the male cell into the oogonium, where it fuses with the oosphere, forming the oospore, which secretes a cell-wall round it. After a period of rest the latter germinates.

In Cystopus (*fig.* 832) the germination takes the form of the production of a number of zoospores, which are set free. In Pythium and other genera it results in the production of a small promycelium, which in time gives rise to spores.

The Saprolegniæ all live in water, being parasitic in some cases, though often saprophytic. The Salmon disease is due to one species of this group. The gonidangia are here club-shaped and give rise to zoospores (*fig.* 834). The sexual organs are

Fig. 832.

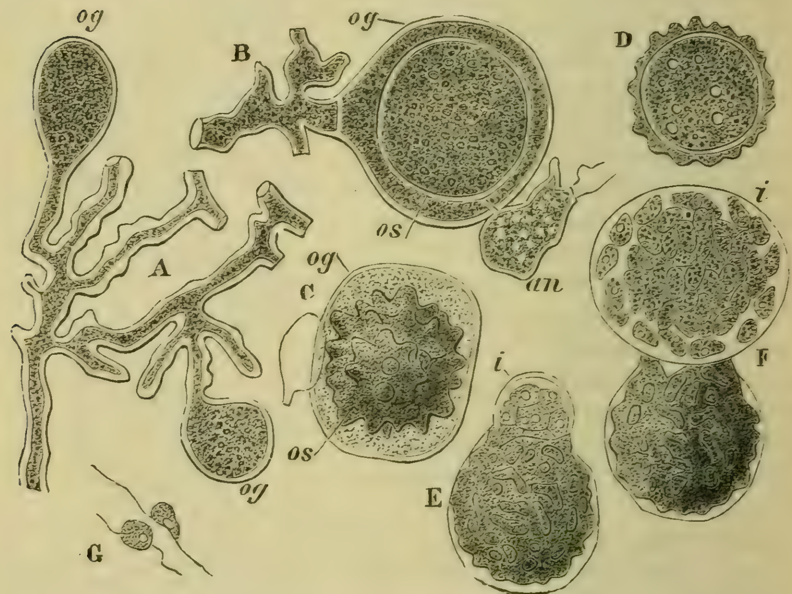


Fig. 832. A. Branched mycelium of *Cystopus*, with young oogonia, *og*, *og*. B. Portion of mycelium bearing oogonium, *og*, with the oosphere, *os* ; and antheridium or pollinodium, *an*. C. Mature oogonium, with *os*, the oospore. D. Mature oospore. E, F. Formation of swarm-spores or zoospores, G, from the oospores. *i*, *i*. Protruded endospore. After De Bary.

similarly produced to those of the last group, but the oogonium contains usually several oospheres (*fig.* 833). In their formation there is no periplasm left. The pollinodia usually send tubes into the oogonium, but there is no passage of the male gamete. The oospheres become oospores without fusion with the latter, that is parthenogenetically.

In the Oomycetes, as in the Zygomycetes, antithetic alternation of generations occurs, but the sporophyte is always small and inconspicuous. It is represented by the oospore itself in such

forms as Cystopus, where it at once gives rise to zoospores; in Pythium, &c., the promycelium is the sporophyte. Some forms have apparently no such alternation, as the oospores give rise to sexual plants.

Sub-Class IV.—Ascomycetes.

In this group the mycelium is made up of a number of cœnocytes, each of the apparent cells into which the hyphæ are

Fig. 833.

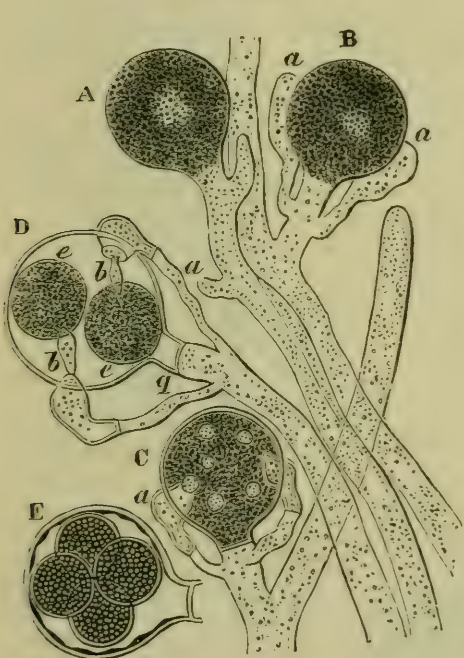


Fig. 834.

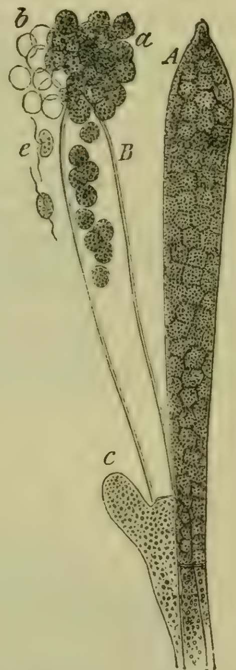


Fig. 833. Oogonia and antheridia of *Achlya lignicola*. The letters A to E indicate the course of development. The protoplasm of a cell or branch of a cell collects into a globular form A, B, and by the formation of a septum, D q, becomes an independent cell (the oogonium). The protoplasm then breaks up into two or more parts, D, e, e (oospheres), which quickly become spherical, as seen in D, secrete a cell-wall E, and become oospores. After Sachs.——*Fig.* 834. Two gonidangia of Achlya. A. Closed. B. Ruptured and allowing the zoogonidia, a, to escape. b. Mother-cells of the latter after escape of e, the zoogonidia, from them.

divided containing several nuclei. The mycelium is thus incompletely septate. The fungi are both saprophytic and parasitic. Sexual reproduction is said to occur in some forms, but it is not undisputed. In many cases complex organs occur which suggest sexuality, but it may be that, as in the Sapro-

legniæ, the actual process does not take place. It is, however, convenient to describe these structures as sexual, while reserving the question of actual fusion of the gametes.

The group derives its name from the fact that whether produced after sexual fusion, or parthenogenetically, the spores arise in closed cells known as *asci*. There is much variety in the mode of origination of the latter, but they agree in that there

Fig. 835.

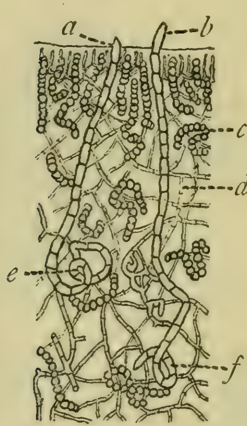


Fig. 837.

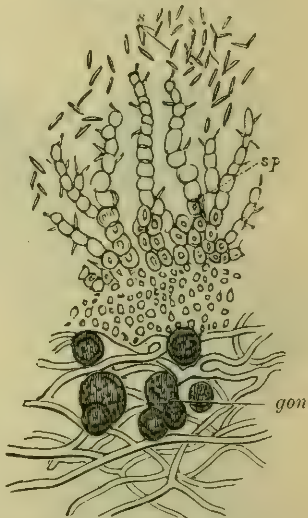


Fig. 836.

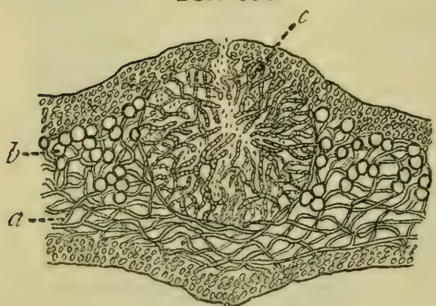


Fig. 835. Section of upper portion of thallus of a lichen, showing archicarps. *a*, *b*. Trichogynes. *e*, *f*. Coiled basal portion of archicarps. *c*. Nostoc filaments. *d*. Fungal hyphæ. After Kny. ——*Fig.* 836. Section of spermogonium of a lichen. *a*. Hyphæ of the thallus. *b*. Algal cells. *c* Sterigmata.——*Fig.* 837. Highly magnified fragment from the wall of a spermogonium of *Parmelia parietina*. *sp*. Articulated sterigmata or spermatophores. *s*. Spermatia. *gon*. Algal cells.

is no case of a differentiated female gamete giving rise to them. The fungi of this group in this respect resemble the Rhodophyceæ of the group of Algæ.

The sexual organs show a great deal of difference in degree of complexity. The female organ is usually an *archicarp* consisting of a coiled portion, known as a *carpogonium*, with sometimes an elongated part, called a *trichogyne* (*fig.* 835). In

many forms the trichogyne is wanting, and only the coiled portion is found. The male organ is sometimes a pollinodium, much like that of the preceding group, and produced in the immediate neighbourhood of the carpogonium. Sometimes it is a filament producing small cells by abstriction. These filaments are known as *sterigmata*, and are borne in special depressed receptacles called *spermogonia* (*figs.* 836 and 837). The separate cells correspond to antherozoids, but are incapable of motion and clothed with a cell-wall. They are known as *spermatia*. The result of the union of the contents of the pollinodium or spermatium with those of the carpogonium is a fructification called the *ascogonium*, which is the sporophyte of the fungus.

In the simplest case, which is that of *Eremascus*, two hyphæ coil round each other. These correspond to the carpogonium and the pollinodium respectively. Their contents are said to fuse, and as the result a large globular body is produced at the apex of the coil, the contents of which divide into eight spores.

In *Eurotium Aspergillus* (*fig.* 838) a little more difference is found between the two hyphæ. The female forms a coil, and from the base of it the pollinodium arises. It becomes closely adpressed to the carpogonium, and fusion of the contents of the two is said to occur. From the base of the carpogonial filament other filaments arise which grow round and envelop it. The coiled carpogonium becomes septated, and from each segment a little protrusion arises which enlarges and becomes an ascus and forms in its interior eight spores. The investment becomes also septated, and forms a thick wall to the whole body. From its cells ingrowths arise which gradually fill up the spaces between the coils of the carpogonium, forming a solid mass of pseudoparenchyma. The body so formed is then known as the ascogonium or *ascocarp*. From the fact that it remains closed and produces its spores internally, it is sometimes called a *cleistothecium*.

The fungus *Collema*, which is generally found in symbiotic relation with an Alga, may be taken as an illustration of another type. The female organ is a septated coiled filament embedded a little below the surface of the organism (*fig.* 835). Its upper end is prolonged into a tapering filament, the trichogyne, which projects above the surface. A spermatium liberated from the spermogonium is floated passively to the trichogyne and becomes attached to it. The walls deliquesce at the point of contact, and fusion of the contents takes place. The trichogyne then withers and the carpogonium develops and pushes its way to the surface, where it expands into a flattened disc which is known as an

apothecium. Hyphæ from the sterile tissue are interwoven with the filaments from the carpogonium, so that the apothecium is derived from both. The surface layer of the apothecium is

FIG. 838

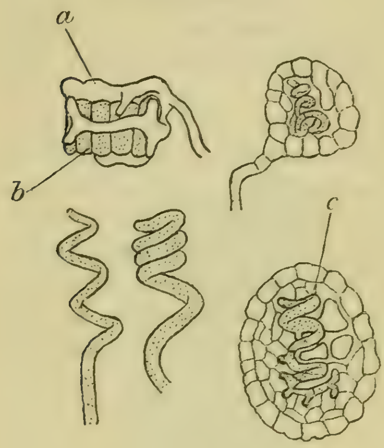


FIG. 840.

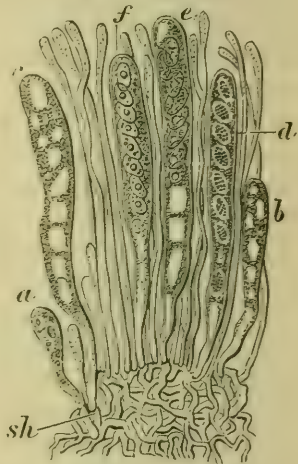


FIG. 839.

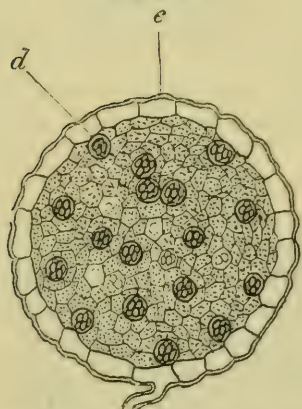


FIG. 841.

Fig. 838. Development of the cleistothecium of *Eurotium.* *a.* Pollinodium. *b.* Carpogonium. *c.* The carpogonium beginning to form asci. After Kny.——*Fig.* 839. Mature cleistothecium of Eurotium. *e.* Wall. *d.* Asci containing ascospores. After Kny.——*Fig.* 840. Hymenial layer of the mycelium or hyphæ of *Peziza convexula.* *a, b, c, d, e, f.* Successive stages of development of the asci and ascospores intermixed with slender paraphyses. After Sachs.——*Fig.* 841. Perithecium of Peziza (natural size), with section showing hymenial layer (slightly magnified). After Kny.

known as the hymenial layer (*figs.* 840 and 841). It consists of a number of asci derived from the carpogonium, and of sterile filaments springing from the vegetative hyphæ. These are

called *paraphyses*. Each ascus develops eight spores from part of its protoplasm, the rest remaining as *epiplasm*.

In some species the fructification is in the form of a deep or shallow cup, sometimes nearly closed. This is called a *perithecium* (*fig.* 841).

The group of the Saccharomycetes is now generally referred to this sub-class. These plants are represented by the *Yeasts*, which have the power of setting up alcoholic fermentation in sugary fluids. They are simple cells of rounded or ovoid form which multiply with great rapidity by a process of budding. When growing rapidly, sometimes chains of cells are formed, owing to the budding taking place before separation of the cells. Under certain conditions, usually when badly nourished, the yeast cell forms four spores by free cell-formation in its interior. There is, however, no sexual apparatus ever produced. Each such cell may be looked upon as an ascus and the four spores as ascospores.

Fig. 842.

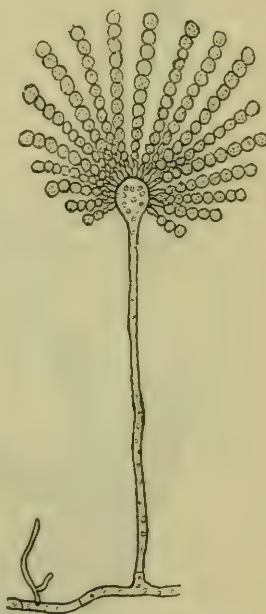


Fig. 842. Stylogonidia of Eurotium, produced by abstriction from sterigmata.

Besides these so-called sexual processes, most of these fungi can produce gonidia in great numbers. They are borne upon erect aerial hyphæ by a process of abstriction from their terminal cells called sterigmata (*fig.* 842). Each sterigma can thus produce a chain of gonidia. Sometimes the aerial hypha or gonidiophore terminates in a single sterigma, sometimes it branches near the apex, forming several. Sometimes the gonidiophores are found in numbers in special receptacles called *pycnidia*.

We have thus an alternation of generations in most members of the group, the ordinary mycelium being the gametophyte, and the ascocarp the sporophyte. Homologous alternation almost always occurs, many gametophytes in succession bearing only gonidia, till one appears which produces the sexual organs. In a few genera, however, no gonidia are found.

A curious case of homologous alternation occurs in some

forms where two kinds of gametophyte are met with. The fungus producing Ergot (*Claviceps*) is an example of this. The first form consists of a feltwork of mycelium, filling the ovary of the Rye or Wheat plant, and giving rise by abstriction to

FIG. 843.

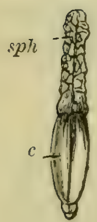


FIG. 844.

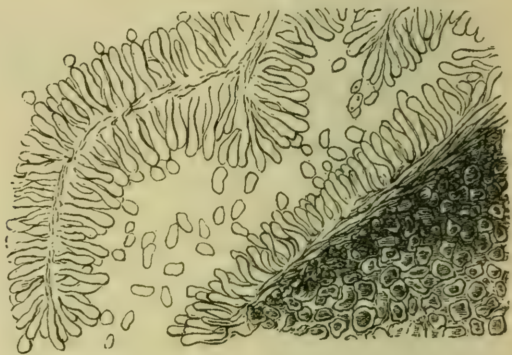


Fig. 843. Young sclerotium, *c*, of *Claviceps* growing up and supplanting the old sphacelia, *sph*.——*Fig.* 844. Section through the junction of the sphacelia with the sclerotium of *Claviceps*, showing formation of gonidia.

FIG. 845.

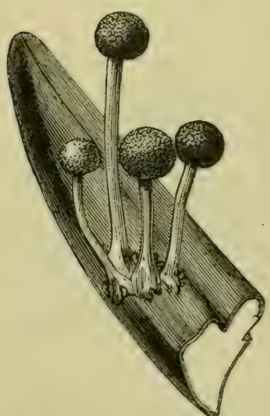


FIG. 846.

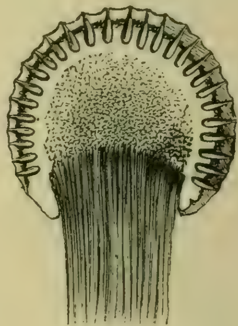


Fig. 845. Portion of the horn-shaped sclerotium of *Claviceps purpurea*, or the Ergot Fungus, bearing four stromata.——*Fig.* 846. Longitudinal section of a stroma, magnified, showing the perithecia. After Tulasne.

numbers of gonidia (*fig.* 844). This form is known as the *Sphacelia*. Later in the year the mycelium becomes very dense and hard, and protrudes from the ear as a black elongated body which is known as a *sclerotium* (*fig.* 843). After a period of rest extending through the winter, the sclerotium germinates, putting

out a number of short protrusions, each composed of a number of hyphæ. These, which are called *stromata*, bear each a rounded head, which is covered by a number of depressions. In each of these is developed a perithecium (*figs*. 845, 846, and 847), the asci of which develop each eight filiform ascospores (*fig*. 848). These, when they germinate on the flowers of the host-plant, again produce the sphacelia form.

Sub-Class V.—Æcidiomycetes.

In this group are included two orders of parasitic plants, which are characterised by a still further degradation of the sexual processes. Indeed it is doubtful if any sexual organs

Fig. 847.

Fig. 848.

Fig. 847. A single perithecium of *Claviceps purpurea*, magnified, showing the contained asci. After Tulasne.——*Fig*. 848. Asci of the same, containing the long slender ascospores. After Tulasne.

exist, though a peculiar form of fructification, the *æcidium*, occurs in some of the members, which is thought by some botanists to be homologous with the ascogonium of the preceding group. The gametophyte is consequently potential and not actual, in most if not in all cases. It is very polymorphic, and bears several different kinds of gonidia, all produced by abstriction.

The most characteristic fungus of this group is *Puccinia graminis*, which forms the *rust* of wheat. It has a very peculiar life history, inhabiting two host plants in different stages of its existence. In the first of these it is found infesting the stems and leaves of Wheat and other grasses, whose tissues are pene-

trated by an incompletely septate mycelium. During the summer this mycelium produces patches of gonidia, each borne upon a short stalk. These develop underneath the epidermis of the host, and, being of a yellow or reddish colour, give the part a rusty appearance. These are known as *uredospores* or *uredogonidia*. These escape by rupture of the epidermis (*fig.* 849, A), and are blown upon other grass plants, where they germinate, and the hypha penetrates the host through a stoma. In the interior a mycelium is produced, which again produces patches of uredospores.

Towards the end of the summer the same mycelium gives

FIG. 849.

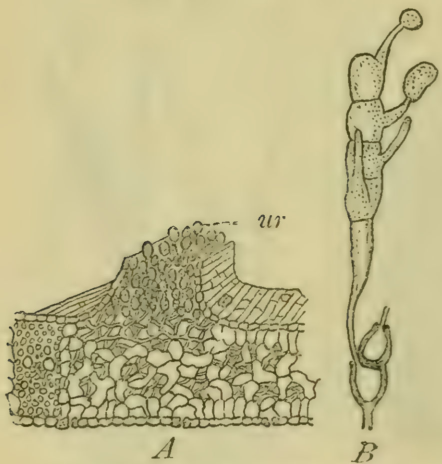


FIG. 850.

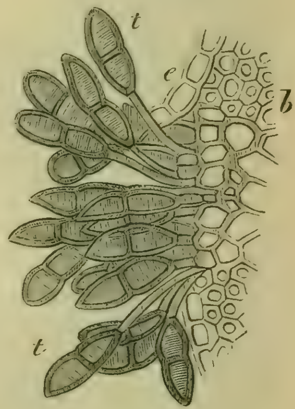


Fig. 849. A. Grass leaf infested with *Puccinia graminis*, showing the uredospores bursting through the epidermis of the leaf. B. Teleutospore germinating and producing promycelium with sporidia.——*Fig.* 850. Teleutospores of *Puccinia graminis* bursting through epidermis of straw. After Kny.

origin to black patches which are visible upon the straw. These are composed of numbers of compound gonidia, two together upon a single stalk, developed as before by abstriction (*fig.* 850). These, which are called teleutospores, or teleutogonidia, have thick black walls and are very resistent. They remain quiescent till the spring, when one or both of the cells germinates, producing a small promycelium, usually of four cells. Each cell puts out a small gonidiophore, from which a small gonidium, called a *sporidium*, is developed by abstriction (*fig.* 849, B). From a resemblance to the cells which abstrict the spores in the next group, these cells are sometimes called *proto-basidia*. The sporidium is a very small thin-walled structure, and from its lightness it is

easily transported by the wind. It is incapable of developing a mycelium upon the grass, but if it falls upon the leaf of the Barberry, it germinates, sending a hypha through the epidermis, instead of penetrating a stoma like the uredospore. The mycelium resulting from this hypha forms a dense network in the intercellular spaces of the leaf. At particular spots upon the leaf brown pustules make their appearance, in which two kinds of receptacles appear. Some on the upper surface of the leaf are much like the spermogonia of the Ascomycetes, and bear the

FIG. 851.

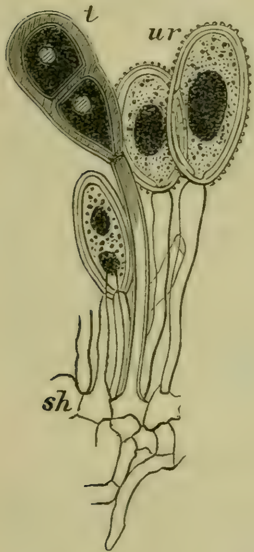


FIG. 852.

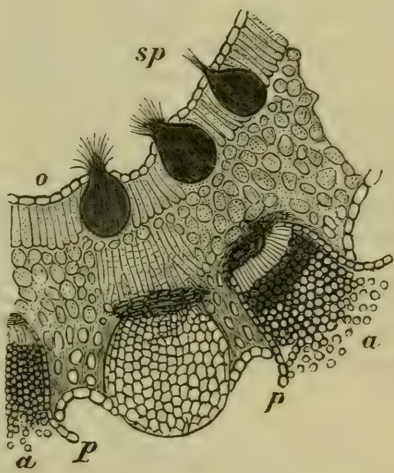


Fig. 851. Group of three uredospores, *ur*, and one teleutospore, *t*, springing from mycelium *sh*.——*Fig.* 852. Section through leaf of the Barberry infested with *Puccinia graminis*. *o*. Epidermis of upper surface of leaf. *sp*. Spermogonia. *p*, *p*. Layers of cells (*peridium*), surrounding *a*, *a*, the æcidium fruits. After Sachs.

same name. They produce spermatia in the same way as the latter. Upon the under surface large spherical bodies are formed (*fig*. 852), containing a hymenial layer of sterigmata which cut off from their apices a succession of spores known as *æcidiospores*. There are large numbers of chains of these thus produced in the globular mass, which is known as an *æcidium* The whole æcidium has a wall derived from the sterile hyphæ When mature it ruptures and the spores escape. These are carried in their turn to other grass plants, and there germinating, reproduce the uredo form, entering the grass through the stomata.

This plant and those like it, which thus inhabit two host-plants in their life cycle, are called *heterœcious*.

There are many of these rusts, which vary in several ways. The compound teleutogonidia sometimes have more than two cells. Sometimes the æcidium form inhabits the same host as the uredo form, when the fungus is said to be *autœcious*. Sometimes again one or the other phase of the life cycle does not occur.

Though the æcidium is held by some to correspond to the ascocarp or ascogonium of the Ascomycetes, no sexual process causing its development has been discovered.

The rusts constitute the family of the Uredineæ, named from the uredo form of the fungus.

The other family included in this sub-class is that of the Ustilagineæ or smuts. They differ from the Uredineæ in not producing æcidia. Like them the mycelium infests the tissue of grasses, ultimately making its way into the ovary of the latter, replacing its normal contents by a mass of black resting gonidia. These when liberated germinate, forming a small promycelium on which sporidia of curious shape are borne. These sporidia sometimes coalesce in pairs, sometimes remain separate. On germination they either produce the original form of mycelium, or give rise to another promycelium bearing sporidia. The latter then produce the first form.

Sub-Class VI.—Basidiomycetes.

This group includes the Mushrooms, Puff-balls, &c. It is characterised by the entire absence of sexual reproductive organs. The mycelium, which is incompletely septate, burrows throughout the substratum on which the fungus grows, and sends up above the surface large fructifications which bear the spores or gonidia. These are formed by abstriction from special cells known as *basidia*, which give the name to the group. The form of the fungus is always that of a potential gametophyte, but the power of producing gametes is absent.

The distinguishing feature of the group is the large sub-aerial fructification or gonidiophore. Several varieties of this are found, of which the most familiar is that produced by the common mushroom (*Agaricus campestris*) (*fig.* 853). A conical or pear-shaped outgrowth appears upon the mycelium, consisting of a number of hyphæ closely cohering together and growing at their apices. The direction of the growth soon changes, the hyphæ spreading outwards to form a prominent head which

extends centrifugally. An annular cavity is formed in this near its lower part, which increases in size as the head extends. The head can now be recognised as distinct from the lower portion of the hyphal mass, and is known as the *pileus*, the lower part or stalk being called the *stipes*. In the air cavity a number of plates or lamellæ are developed, which radiate from the centre to the circumference. These form the gills of the mushroom, and on them the spores or gonidia are developed. As the growth of the stipes proceeds, the part of the pileus below the air cavity

FIG. 853.

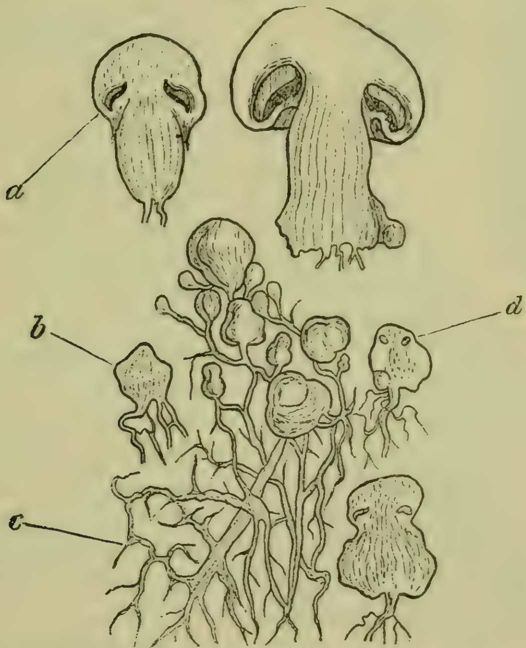


Fig. 853. Development of the Mushroom. *c*. Mycelium. *b*. Early stage of the development of the gonidiophore. *d*. Later stage, showing origination of the gill-chamber. *a*. Later stage, showing commencement of formation of the gills. After Sachs.

becomes very much stretched and forms a membrane, extending from the stipes to the lower margin of the pileus. It ultimately ruptures and leaves the gills exposed. This membrane is known as the *velum partiale*. The gills are composed of hyphæ, which run parallel along their length, ultimately curving slightly outwards. These constitute the *trama* (*fig*. 854, *f*), and are covered by the *hymenial layer*, which is composed of short cells derived from the hyphæ of the trama, set at right angles to its long axis. These cells are of two kinds, sterile ones, or

paraphyses, and those which give rise to the spores, the basidia. Each basidium puts out four delicate outgrowths, closely resembling those of the promycelium of the Uredineæ, and from each of these a single gonidium or spore is abstricted. These, from their mode of origin, are known as *basidiospores* or *basidiogonidia* (*fig.* 854, C, *g*).

Fig. 854.

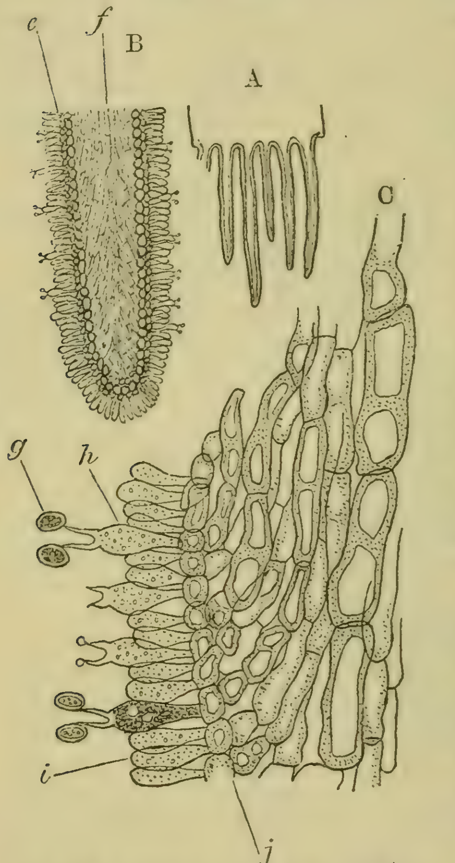


Fig. 854. A. Section of five gills of the Mushroom. B. One gill more highly magnified. *f.* Trama. *e.* Hymenial layer. C. Hymenial and sub-hymenial layers. *h.* Basidia. *g.* Basidiospores. *i.* Paraphyses. *j.* Sub-hymenial layer. After Sachs.

The form of the fructification varies a good deal in different groups. In some the hymenium is exposed from its first formation; in others it is covered for a time by the *velum partiale*; in yet others it is always surrounded by a membrane, which is then known as the *peridium*, as in the Gasteromycetes, or the *velum universale*, as in some Agaricinæ. The hymenium is also variously arranged; in the true mushrooms it covers the gills as described; in the family Polyporeæ it lines pits or tubes on the under surface of a flattened expansion; in the Gasteromycetes it is formed in the interior of the fructification in a number of chambers.

The basidia are usually unicellular, but in one group, the Protobasidiomycetes, they are divided by septa, sometimes transverse, sometimes longitudinal, forming four cells, each of which produces a single gonidium. These forms approach the promycelium of the Uredineæ very closely.

Vegetative reproduction occurs in this group, by the formation of gemmæ, which commonly arise on the vegetative

mycelium as oidium cells (page 73). Some of the Basidiomycetes also produce sclerotia, masses of closely matted hyphæ which may become detached from the mycelium and germinate after a period of quiescence.

In recent years the investigations of Brefeld and his pupils have led to a different classification of the Fungi, for which there is much to be said.

The Myxomycetes are taken out of the group and made a separate class, of equal position to the Algæ and Fungi, great stress being laid on their resemblance to the animal Mycetozoa or Rhizopods.

The Fungi proper are subdivided into three classes, and these into sub-classes as under :—

CLASS I. PHYCOMYCETES.
- Sub-Class 1. Zygomycetes.
- Sub-Class 2. Oomycetes.

CLASS II. MESOMYCETES.
- Sub-Class 1. Hemiasci.
- Sub-Class 2. Hemibasidii.

CLASS III. MYCOMYCETES.
- Sub-Class 1. Ascomycetes.
  - Series 1. Exoasci.
  - 2. Carpoasci.
- *Additional.* Ascolichenes.
- Sub-Class 2. Basidiomycetes.
  - Series 1. Proto-basidiomycetes.
  - 2. Auto-basidiomycetes.
- *Additional.* Basidiolichenes.

Additional. Fungi imperfecti.

According to this school these groups can be arranged in the form of a tree, indicating the probable line of descent or succession of forms. The Phycomycetes are held to be the primitive type and to be descended from sporangia-bearing Chlorophyceæ.

Phycomycetes

Zygomycetes | Oomycetes

Hemiasci | Hemibasidii . . *Mesomycetes.*

Ascomycetes | Basidiomycetes . *Mycomycetes.*

The Phycomycetes form the lowest group and include all the forms which as well as asexual show sexual reproduction by fusion of differentiated gametes. They thus include the Mucorini, the Peronosporeæ, and the Saprolegniaceæ.

The Mesomycetes comprise the intermediate forms between the Phycomycetes and the Ascomycetes and the Basidiomycetes respectively. They approach the latter in their vegetative organs, especially their incompletely septate mycelium. They differ from them in not possessing definite asci or basidia. They have no sexual organs, differing thus from the Phycomycetes.

The Hemiasci are a small and comparatively unimportant group; the Hemibasidii include the Ustilagineæ, or smuts.

Through the Mesomycetes the line of descent passes to the Ascomycetes on the one side and the Basidiomycetes on the other, which together form the group of the Mycomycetes. These have septate hyphæ, and produce their spores at some time or other in asci or on basidia. Sexual reproduction is unknown.

The Ascomycetes embrace, generally speaking, the forms included under the same name in the older classification, except that the Saccharomycetes are excluded. The Ascolichenes are held to belong to this group and are not put into a separate class. The Ascomycetes are divided into two series, the Exoasci, where the asci are simple and free, and the Carpoasci, where they are gathered into the various forms of fructification already described.

The Basidiomycetes are a larger group than in the old system, as the Æcidiomycetes are included in it. The latter are referred to the series Protobasidiomycetes on account of the mode of germination of the teleutospore, which gives rise to what was formerly called a promycelium on which were borne sporidia. This promycelium is held to be a *protobasidium*, from each cell of which a basidiospore is segmented. The Autobasidiomycetes comprise what under the older system were called Basidiomycetes, except the Auriculariaceæ and the Tremellaceæ, which form with the Uredineæ the first series.

The Basidiolichenes are held to be members of this group, though not referable to either of the two series.

Finally, the Saccharomycetes are separated from the rest on the ground that their life history is very imperfectly known, and that they probably are only stages in the life cycle of some polymorphic form of the higher Fungi. They are classified as an additional group under the name *Fungi imperfecti.*

CLASS III.—LICHENES.

The propriety of considering the Lichens as a separate class is perhaps open to discussion. Before their true nature was understood they ranked as such, but when they were ascertained to be largely fungal in their composition, and to contain algæ in their tissues, they were perhaps hastily relegated to the Fungi, assuming them to be parasitic on the algæ within them. Further study has shown them to be symbiotic organisms, the

FIG. 855.

Fig. 855. A. *Usnea barbata,* a fruticose lichen (natural size). B. *Sticta pulmonacea,* a foliaceous lichen. *a.* Apothecia. After Sachs.

alga and the fungus living together to the mutual advantage of both. The constituents may also sometimes vary, the same algæ growing with different fungi and *vice versa.* They may consequently be restored to something of their old position.

The lichens are thallophytes of various form, living on old trees, rocks, &c., and presenting always a peculiar withered appearance. According to their habit, they may be divided into *fruticose*, *foliaceous*, and *crustaceous* lichens.

The fruticose forms have an erect thallus, which branches in a somewhat shrubby fashion. A typical lichen of this type is *Usnea barbata* (*fig.* 855, A). The *foliaceous* ones are flattened and grow closely and pressed to the substratum. The thallus is wavy and its margin lobed. The *crustaceous* forms are usually very indistinct, their outline indefinite, and only their fructification distinctly seen. They become so attached to their substratum that they cannot be detached from it completely without injury (*fig.* 856).

FIG. 856.

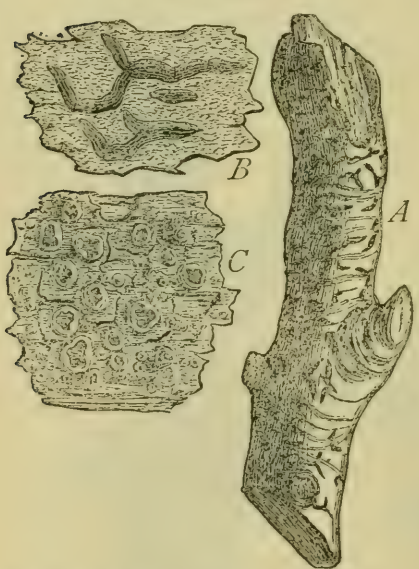


Fig. 856. A, B. *Graphis elegans*, a crustaceous lichen growing on the bark of the Holly. A. Natural size. B. Slightly magnified. C. *Pertusaria Wulfeni*, another crustaceous lichen (slightly magnified). After Sachs.

In composition the thallus consists of a fungoid mycelium, which is very closely matted together. It includes in its substance certain algæ, which may be distributed throughout it or confined to a definite layer near the upper surface, constituting the *homoiomerous* and *heteromerous* kinds respectively. In the former case the algæ generally belong to the Cyanophyceæ, and in the latter to the Chlorophyceæ. This distinction is, however, by no means absolute. The fungal constituents are chiefly referable to the sub-class Ascomycetes, and so great is their prominence that the whole group has by some botanists been described as a family of this sub-class. Other fungi, however, are now known to enter into the symbiotic relationship with algæ, especially several belonging to the Basidiomycetes.

The proof of the true character of the lichens is based upon the facts that the two organisms can be cultivated separately, and that if the spores of one of the fungi be sown amongst some of the algæ the composite organism can be produced.

A section of the body of one of the heteromerous foliaceous lichens is shown in *fig.* 857, where the distribution and character of the fungal mycelium are shown. *g* is the layer of

algæ which are symbiotic with the fungus. In the fruticose forms the centre of the branches is occupied by a dense strand of hyphæ running longitudinally. This is surrounded by a looser layer which is in turn enclosed by a compact cortex. The algæ are found in the loose tissue.

The reproductive organs of the lichen are always produced by the fungal constituent. The fructification is usually an apothœcium produced after the fusion of a spermatium with the trichogyne of an archicarp, as described in the case of Collema (page 82).

The hymenial layer of the fructification of the form into which a basidiomycete enters has basidia and paraphyses like those of the ordinary Basidiomycetes.

FIG. 857.

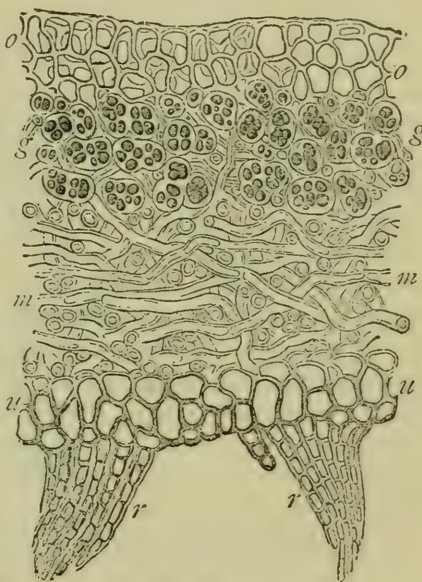


Fig. 857. Transverse section of the thallus of *Sticta fuliginosa* ($\times$300). *o.* Cortical layer of the upper side; *u*, of the under side. *r*, *r*. Attaching fibres. *m*. Medullary layer, consisting of fungal hyphæ. *g*. The algal cells.

The mode of growth of the lichen is in most forms determined by the fungus constituent, the algæ dividing and multiplying as the thallus extends. In some cases the algæ are more prominent, the fungus-hyphæ being very fine and delicate. The algæ occupy nearly the whole substance of the branches, and are covered by a gelatinous envelope derived from their cell-walls. In this the delicate fungus-hyphæ ramify.

The lichens reproduce themselves vegetatively by forming peculiar gemmæ termed *soredia*. These are composed of a small bundle of fungal filaments investing a few algal cells. They are cast off from the surface of the thallus and speedily reproduce it.

The Algæ which take part in the composition of lichens are usually very simple unicellular or filamentous forms, such as Nostoc, Chroococcus, Scytonema, Protococcus, &c. Rarely higher forms are found, such as members of the Coleochætaceæ.

CHAPTER IV.

Group II.

BRYOPHYTA.

The plants of this group show a great advance in complexity of structure when compared with the Thallophyta. There is a well-marked antithetical alternation of generations, the gametophyte giving rise to the sporophyte uniformly as the result of the fertilisation of a female sexual cell. The spore on germinating always produces a gametophyte.

The gametophyte is the body which is usually termed the plant, the sporophyte is a stalked spherical or ovoid structure which arises upon it and never has a separate existence. The gametophyte shows considerable morphological differentiation; in the lower forms it is a thallus; in some a little higher it is a thalloid stem bearing a few rudimentary leaves; in the highest forms it is a leafy shoot. There are never any true roots, but a number of unicellular root-hairs, or multicellular filaments, attach it to the soil. It always contains chlorophyll, the arrangement of the plastids presenting considerable variety.

The gametophyte consists of two parts. When the spore germinates it does not at once produce what we recognise as the plant, but gives rise to a structure called the *protonema* (*fig.* 858), which is sometimes a flattened plate-like body and sometimes a much-branched filament. Upon this protonema the plant arises usually as a lateral bud, which grows up into the form of the adult gametophyte.

The protonema contains chloroplastids in all its cells; it exists usually for a short time only, though in some of the Mosses it persists for a long period. Generally in the Hepaticæ the protonema gives rise to only one plant; in the Mosses, on the other hand, several may spring from it.

The anatomical differentiation of the gametophyte is not very great. The tissue is nearly all parenchymatous, but in some of the Mosses there is in the axis an indication of vascular

tissue occuping the centre. This is, however, very rudimentary, true vessels or tracheïds never being found. A similar tissue occurs in the midribs of the leaves in some species. The epidermis is not completely differentiated and bears no stomata. The apical meristem is usually well defined, and consists sometimes of a single apical cell and sometimes of a group of such cells.

The sexual organs, borne only on the gametophyte, are of two kinds, *antheridia* giving rise to *antherozoids* or *spermatozoids*, and *archegonia*, containing each an *oosphere*. In most cases they arise in groups, often on special receptacles, or at the apices of leafy shoots. They are generally surrounded by some

FIG. 858.

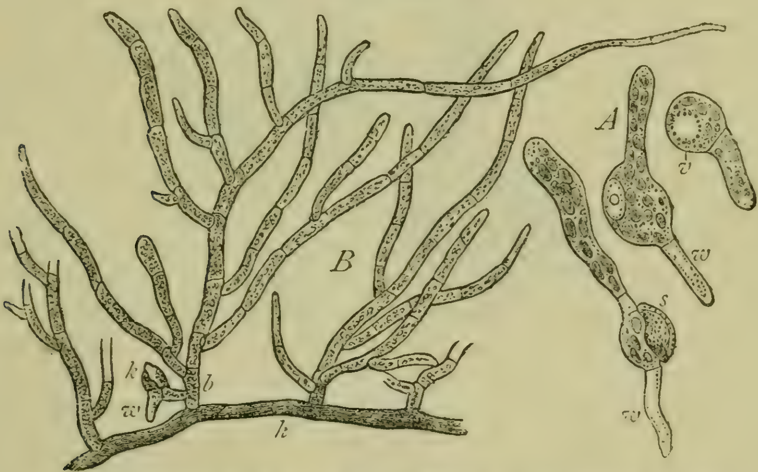


Fig. 858. Protonema of Moss. A. Early stages of germination of spore. B. Developed protonema on which young bud, *k w*, is formed, which will give rise to the moss plant. After Sachs.

arrangement for protection, being either embedded in the tissue of the receptacle or furnished with foliaceous investments. The antheridia are club-shaped, spherical, or ovoid bodies, furnished with a stalk (*figs*. 859 and 866). They consist of a wall composed of a single layer of cells, and a mass of cells in the interior, each of which gives rise to a spirally coiled body furnished with two long cilia and known as a spermatozoid or antherozoid. The cells in which the latter bodies are developed are known as *mother cells*. When the antheridium is mature it bursts, and the mother cells escape, the spermatozoids being discharged from them later (*fig*. 860, A). Each antheridium produces a large number of the latter.

The archegonia are flask-shaped bodies, provided with a short stalk and a long neck (*fig.* 867). The swollen portion at the base is the *venter* and contains the oosphere. The wall of the venter is continued upwards to form the neck. The axis of the archegonium is occupied by a number of cells, the lowest one of

FIG. 859.

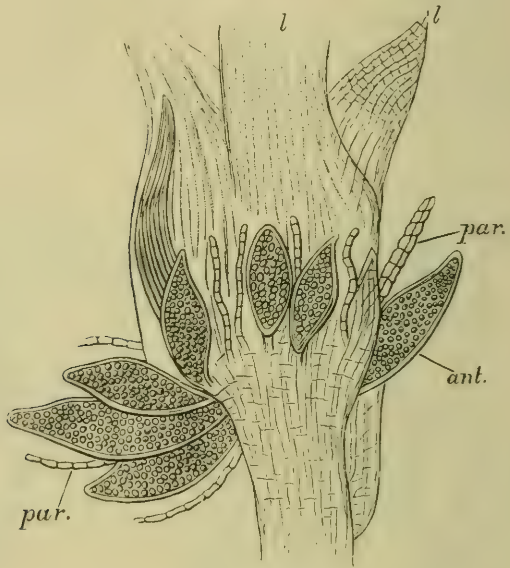


FIG. 860.

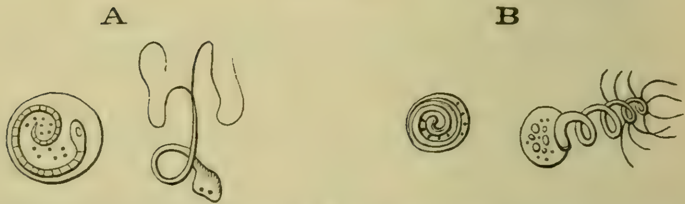


Fig. 859. Apex of fertile shoot of Moss (*Polytrichum*) bearing antheridia, *ant*, and paraphyses, *par*. *l*. Leaves of the shoot.——*Fig.* 860. A. Antherozoids of Moss (×1200). B. Antherozoids of Fern (×700).

which gives rise to the oosphere and the remainder are known as the neck-canal-cells. Before forming the oosphere the lowest cell divides into two, of which the upper one is the smaller, and is known as the *ventral canal-cell*. The other one is the oosphere. The terminal cells of the neck separate when the archegonium is mature. The neck-canal-cells and the ventral

canal-cell become converted into a kind of mucilaginous material, so that a spermatozoid can make its way down the neck to the oosphere, and, fusing with it, form the zygote or oospore.

The process of fertilisation is rendered possible by the fact that the surface of the plant is generally moistened by rain or dew. The liberated spermatozoid can make its way about in this moisture, swimming by means of its cilia. It appears to be attracted to the archegonium by the mucilaginous contents of the neck, which escapes when the lid-cells of the neck separate. This is said to contain a sugar, possibly cane-sugar, which is the attractive matter.

The oospore germinates at once, without becoming detached from the archegonium. It divides into two cells by a wall, known as the basal wall, forming an epibasal and a hypobasal half. The former gives rise, by further segmentation and division, to the body of the sporophyte, which is a capsule known as the *sporogonium*. The hypobasal cell usually in a similar way develops a structure known as the *foot*, which attaches the young sporogonium to the gametophyte. There is no continuity of tissue, however, between the two ; the foot forms a means of attachment only, and serves to absorb nutriment from the gametophyte. In some forms the foot is not developed from the hypobasal cell, which does not divide at all, but remains rudimentary and functionless. Then a foot is derived from the lower part of the mass which is of epibasal origin. In the Riccieæ there is no foot, but both hypobasal and epibasal cells go to form the capsule. Sometimes the capsule is developed only from the upper part of the epibasal mass, the lower part forming a more or less elongated seta or stalk.

As this development takes place from the oospore *in situ*, the growth of the sporophyte is attended by changes which take place in the archegonium. The venter of the latter grows as the sporophyte increases and forms an investment to it which in the forms with sessile sporogonia, remains surrounding it till the spores are ripe. In the stalked forms it is ruptured by the elongation of the seta and carried up on the top of the capsule. This investment is known as the *calyptra*. When it is ruptured the part which remains at the base of the seta and forms a sheath to it, is known as the *vaginula*.

The body of the sporogonium soon shows a differentiation into an external portion known as the *amphithecium* and an internal part called the *endothecium*. In the higher forms an air space arises in the inner part of the amphithecium, which is

bridged over by strands of cells. The amphithecium gives rise generally only to the wall of the capsule, but in one or two families the sporogenous tissue is derived from it. In most cases the latter springs from either the whole or part of the endothecium. In the latter case a central portion of the tissue remains sterile and constitutes the *columella.*

The spores are derived from a mass of cells which are early marked off by the richness and granularity of their contents. These are known as the *archesporium.* In most cases in the Hepaticæ the whole of the endothecium becomes sporogenous; in the remainder (Anthocerotaceæ) the archesporium is the inner layer of the amphithecium. In the Mosses it is generally the outer layer of the endothecium; the Sphagnaceæ forming an exception, behaving like Anthoceros. In the genus Archidium of the Mosses the sporogenous tissue is found in the endothecium, but is not regularly arranged as in the other groups.

In the Hepaticæ the archesporium consists of cells which are of two kinds, some sporogenous, giving rise to spores, others sterile, generally becoming elongated and narrow, with a peculiar spiral thickening on their walls. These are known as *elaters;* they help to disperse the spores when the capsule opens, becoming suddenly elongated by virtue of the longitudinal extension of the spiral band. Elaters are absent from one family of the Hepaticæ. the Riccieæ, where all the archesporial cells are sporogenous.

The sporogenous tissue of the archesporium consists of a number of cells with granular contents. Sometimes a good deal of cell-division goes on in this area, sometimes not. Eventually what are known as the *mother cells* of the spores constitute its substance. In each of these four spores are produced by free cell-formation in the way already described. They are situated at points corresponding to the four angles of a tetrahedron, and the groups are often spoken of as *tetrads.* Before the spores are fully developed the mother cells separate from each other, and later the spores themselves are set free from the latter, each being now a mass of protoplasm, covered by a cell-wall of two coats which the latter has secreted round itself.

The spores are liberated by the rupture of the capsule or its decay. When rupture takes place it may be irregular, or by splitting into valves, or by the separation of the upper portion in the form of a lid known as the *operculum.*

The sporogonium thus formed shows a certain morphological differentiation, there being in the segmentation of the zygote an indication of the formation of root and shoot, the latter being the

result of the development of the epibasal cell while the root is represented by the body developed from the hypobasal one (see vol. i. p. 11). The shoot is not differentiated morphologically, always being a thallus and never bearing leaves.

Besides the regular sexual reproduction, leading to antithetical alternation of generations as described, the gametophyte may and often does reproduce itself vegetatively, giving rise to a kind of homologous alternation also. It rarely possesses the power of forming gonidia, which we have seen to be so common among

Fig. 861.

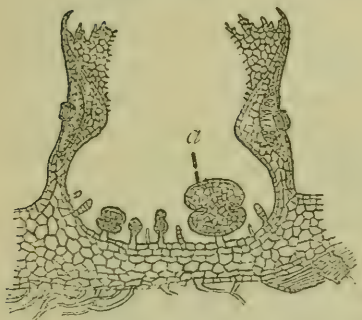


Fig. 862.

Fig. 861. Section of cup-shaped receptacle of Marchantia, in which gemmæ, *a*, are being developed.——*Fig.* 862. A. *Aulocomnion androgynum*, showing gemmæ borne upon a long stalk. B. Collection of gemmæ magnified.

the Thallophytes. It often, however, produces *gemmæ* upon some part of its surface. These gemmæ have a very varied distribution; in many Hepaticæ they arise in cup-shaped receptacles upon the upper surface (*figs.* 861 and 866); in others they are developed upon the leaves; in the Mosses a collection of them is sometimes found upon a long stalk (*Aulocomnion*) (*fig.* 862), or they may occur upon the axis or on the root hairs. They are generally flattened masses of cells, sometimes with definite growing points. Most mosses can put out protonemal filaments from various parts of their surface, which can develop new plants as did the original protonema. Frequently branches are separated from the plant by the dying away of the older tissue at their bases, and these then become fresh plants.

The Bryophyta include the two classes of the Hepaticæ or Liverworts and the Musci or true Mosses.

Class IV.—HEPATICÆ (LIVERWORTS).

The differences which are met with between this group and the succeeding one chiefly concern the sporophyte. In the Hepaticæ the sporogonium is never set free from the calyptra till the spores are mature; the calyptra is never carried up as a cap to the sporogonium, but the whole of it remains as a vaginula; there is no gradual elongation of the seta. Except in the Anthocerotaceæ there is no columella in the sporogonium, but the whole of the endothecium becomes the archesporium; except in the Riccieæ sterile cells, generally elaters, are developed as well as spores from the archesporial tissue. The vegetative body is less differentiated anatomically than in the Mosses; there is never any vascular tissue indicated in either sporophyte or gametophyte, nor are stomata present in the epidermis of the former, except in Anthoceros.

There are two types of structure found in the group, in one of which the gametophyte is a thallus or thalloid shoot, in the other it is a leafy shoot. These are spoken of as *thallose* and *foliose* respectively. The former include the two orders Marchantiaceæ and Anthocerotaceæ, the latter are found among the Jungermanniaceæ.

Thallose Liverworts.—A typical representative of the thallose liverworts is *Marchantia polymorpha*, the structure of which may be described in detail. From the spore there is developed a small protonema, which, at first filamentous, expands into a flat cellular plate, on which arises by budding the body of the plant. This has a thick creeping dichotomously branching thalloid stem, from the under side of which a number of root hairs or rhizoids are given off. It also bears on the lower surface two rows of scaly leaves. The upper surface is somewhat corrugated and bears the sexual organs on special receptacles or gametophores; it also gives rise to a number of circular gemmæ cups or *cupules*, in which the gemmæ arise from superficial cells (*fig.* 866).

The shoot is dorsiventral, the two surfaces showing marked differences in structure.

The upper surface is marked by somewhat indistinct lines, dividing it into a number of lozenge-shaped or rhomboidal areas, in the centre of each of which is a peculiar opening or pit leading into an air-chamber, which is bounded above by a single layer

of cells forming the upper epidermis. From the bottom of this cavity arise a number of short filaments which contain numerous chloroplastids (*fig.* 863). The pit or opening is bounded by a number of tiers of cells, constituting what is sometimes called a *stoma*. It is not, however, a true stoma, as the cells have no power of opening or closing the aperture (*fig.* 864).

Below the layer of air-chambers the thallus consists of several layers of elongated thin-walled or but slightly thickened parenchymatous cells which have no intercellular spaces and which contain few chloroplastids. These cells become smaller and more compact as the ventral surface is approached. The outer layer of these is not especially marked off as a lower epidermis.

The root hairs or rhizoids are long and unbranched. Some

FIG. 863.

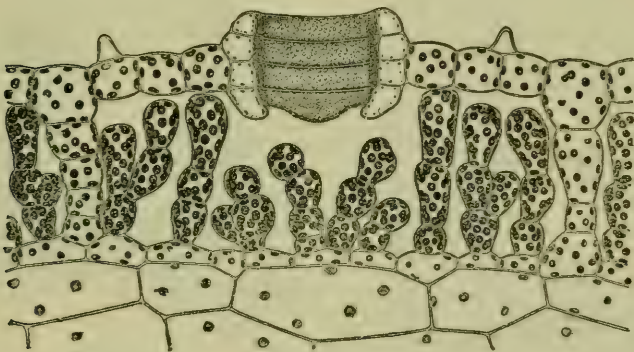


Fig. 863. Section through an air-chamber of the surface of the thallus of Marchantia, showing chlorophyllaceous tissue and stoma. After Kny.

of them contain peculiar peg-like projections of cellulose in their interior.

The thallus grows by the divisions of a group of apical cells which are situated in a depression at the anterior end. The branching is truly dichotomous.

The cupules bearing the gemmæ spring from the air-chamber layer, of which they are outgrowths. Their walls show similar air-cavities to those of the rest of the shoot (*fig.* 865). The gemmæ themselves arise from single cells of the epidermis of the base of the cupule, which elongate upwards and segment into two, of which the lower forms a stalk, while the former develops into a somewhat circular plate, with a conspicuous notch or depression on each side. In these depressions the

growing points are formed. Each gemma is several cells thick in the centre, but the layers thin out towards the margin, where it is only one cell thick. When it falls to the ground after liberation from the cup, the lower surface puts out root hairs and the upper takes on the structure already described. There is at first no difference in structure between the two sides; whichever happens to come in contact with the ground becomes the ventral one. The gemma contains chloroplastids.

Marchantia is a diœcious form ; some shoots give rise to antheridia, others to archegonia.

Both these organs are borne on special gametophores, which spring from the upper surface of the thallus. The antheridiophore

Fig. 864.

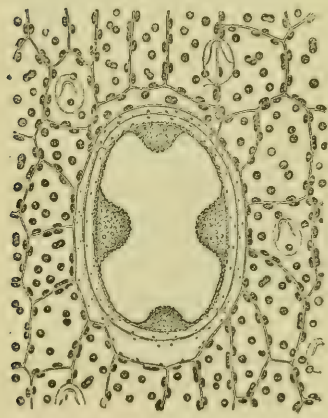


Fig. 865.

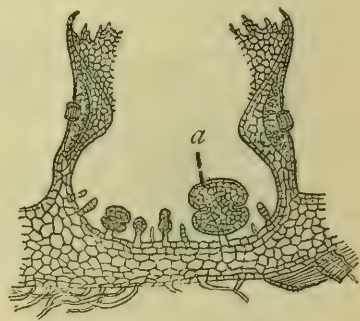


Fig. 864. Surface view of the so-called stoma of Marchantia (×250). After Kny.——*Fig.* 865. Receptacle of Marchantia with gemmæ, *a*.

(*fig.* 866, *d*) is a thick fleshy stalk which spreads out at the summit into a somewhat flattened circular disc, which is lobed at its margins. The disc has several growing points, each producing antheridia, in acropetal succession, which are seated in depressions on its upper surface. The surface of the disc contains air-chambers like those of the rest of the thallus. The antheridia have the structure already described; the depressions in which they are seated are flask-shaped, and only communicate with the exterior by a narrow canal.

The archegoniophore is somewhat more complex. Like the antheridiophore, it is a long stalked body, crowned by a disc. The latter is not a flattened structure, but consists of eight arms or branches radiating from the centre of the stalk, some-

what like the ribs of an umbrella. The archegonia are developed on its under surface in the angles between the ribs and the stalk (*figs.* 867 and 868).

The elongation of the stalk is proceeding while the arche-

FIG. 866.

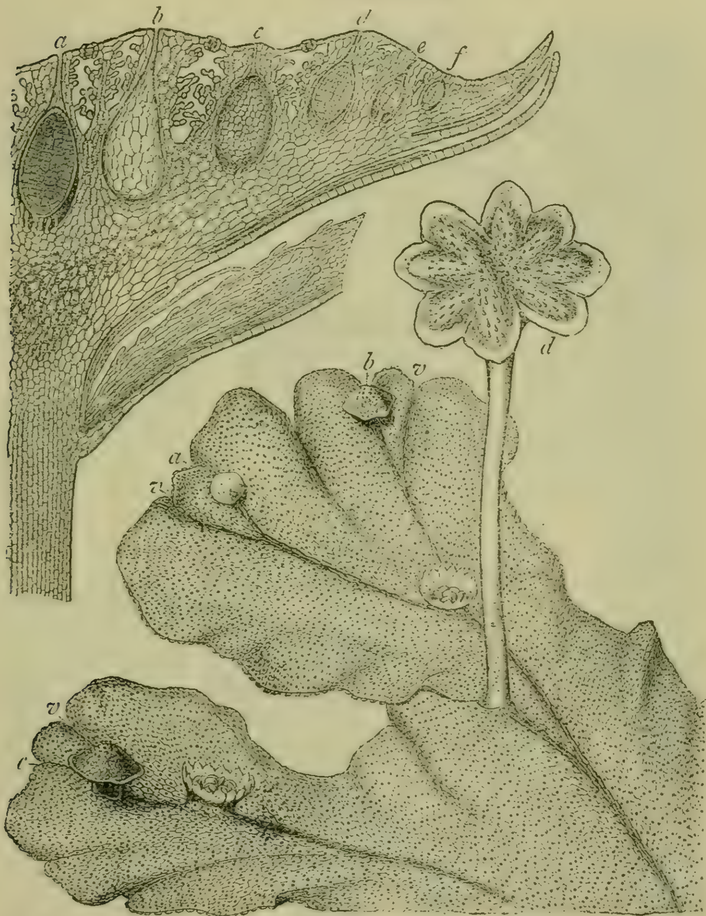


Fig. 866. Thallus of Marchantia with gemmæ cups, *b*, and antheridiophore, *d*. The upper figure is a section through part of *d*. *a*, *b*, *c*, *d*, *e*, *f*. Antheridia in depressions in successive stages of development. After Kny.

gonia are being developed, and they do not spread out freely till fertilisation is effected.

The structure of the archegonia has been already described. They are not embedded in the tissue of the receptacle as are the antheridia, but they are invested by a peculiar outgrowth from it, called the *perichætium*, which often surrounds a group

of them. This springs from the air-chamber layer, but thins out as it grows, forming a membranous structure which is very much dissected or lobed. Besides this perichætium, another membrane, the *perigynium*, grows up from the base of each

Fig. 867.

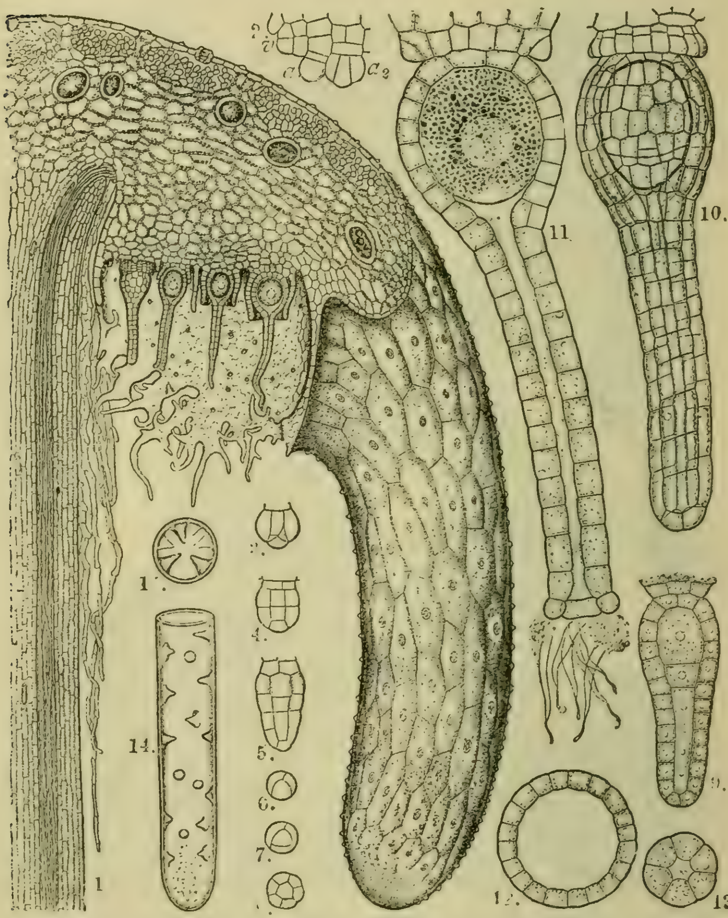


Fig. 867. Archegoniophore of Marchantia, bearing archegonia on under surface. 2, 3, 4, 5, 9, 10, 11. Successive stages in development of archegonia. 14. Root hair with characteristic thickening on the walls. After Kny.

archegonium itself, surrounding it as a kind of open sac as it approaches maturity.

Both the antheridiophore and the archegoniophore are compound, being composed of two coherent branches, the ventral surfaces of which are consequently internal. From these ventral sur-

faces root hairs are originated which may be found, on section of the structure, passing down the centre of the stalk.

The sporophyte or sporogonium arises in the manner described for the whole group. After the division of the oospore

FIG. 868.

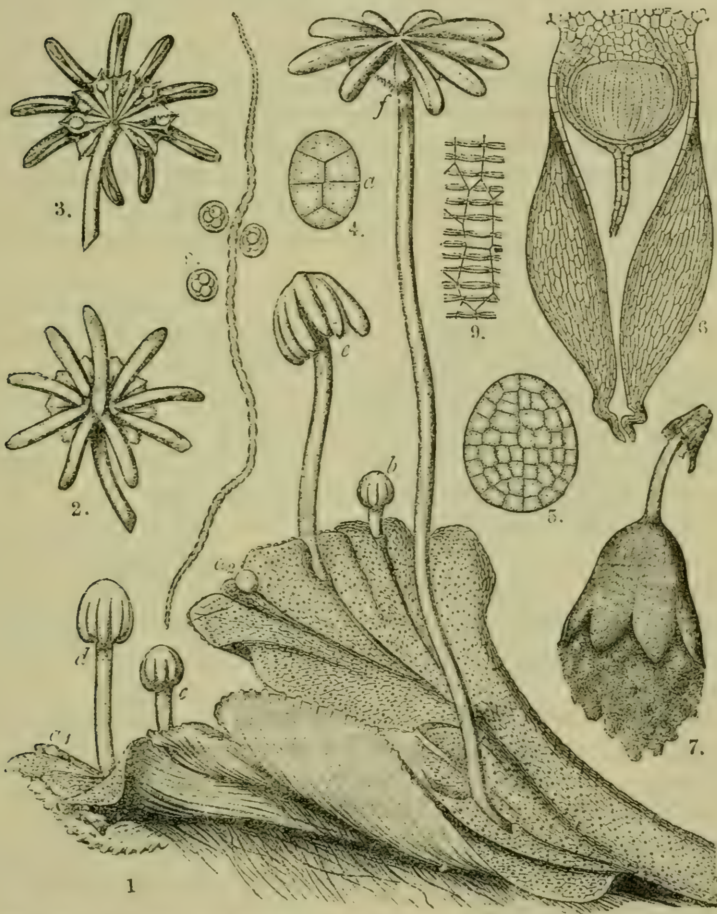


Fig. 868. 1. Thallus of Marchantia bearing archegoniophores. *a*, *b*, *c*, *d*, *f*. Successive stages in their development. 2, 3. Upper and under appearances of archegoniophore when the sporogonia are mature. 6. Young sporogonium. 7. Adult sporogonium dehiscing and discharging the spores. 8. Elater, with mother cells of spores adhering to it. After Kny.

into epibasal and hypobasal segments, two other walls are formed at right angles to each other and to the basal wall, dividing the oospore into octants. The hypobasal octants give rise to a somewhat bulky foot, while the epibasal ones

develop the capsule. All the cells of the endothecium go to form the archesporium, which gives rise to the spore mother cells and to the elaters. The latter are very hygroscopic, and assist in the disseminating of the spores when the capsule opens. When mature, the capsule is forced out of the calyptra by the elongation of a short seta, or stalk, developed from the hypobasal region by intercalary growth. It then opens longitudinally by a number of fissures, and the spores are liberated.

Other members of the thallose group show certain differences from Marchantia. In the lower forms the sexual organs are not borne upon special gametophores, but arise from the ordinary dorsal surface of the thallus. In some the plants are not diœcious, the same thallus producing both antheridia and archegonia; in some Riccias both organs occur together in the same sorus.

In *Anthoceros* and *Blasia*, chiefly on the under surface of the shoots, various cavities occur which are filled with mucilage. In these, quantities of the Alga *Nostoc* live symbiotically. The cavities become irregularly septate in consequence of filamentous outgrowths from the cells of their walls.

Anthoceros is peculiar also in the fact that its chloroplastids contain pyrenoids like those of the Algæ.

The sporogonium of Anthoceros is peculiar in two respects. Its endothecium is sterile and forms a columella, while the archesporium is developed from the inner layers of the amphithecium. It continues to elongate by basal growth, forming a long pod-like body which dehisces from the apex downwards by two valves.

Foliose Liverworts.—The foliose liverworts have a dorsiventral axis bearing leaves which are generally of two kinds. The ventral surface produces a row of very rudimentary ones, which are known as *amphigastria*, while on the lateral faces are developed the ordinary foliage leaves. Root hairs also spring from the ventral side, and mucilaginous secreting hairs occur near the growing point.

The growth in length is carried out by a single apical cell, which is sometimes two-sided, and hence cuts off two series of segments. In some forms the apical cell is a three-sided pyramid. Each segment produces a leaf and also contributes to the increase of size of the stem. The branching of the axis is usually monopodial.

Vegetative reproduction is carried out by means of gemmæ, as in Marchantia, but the gemmæ are, as a rule, simpler in

structure, often being composed of only one or two cells. They arise either from the margins of the leaves or from the axis near its apex.

The antheridia are stalked somewhat globular bodies which are not sunk in the tissue as in Marchantia, but arise singly or in groups on the shoot near its apex, in the axils of the leaves.

The archegonia are developed later, sometimes from the same shoot as the antheridia. They are sometimes solitary, sometimes in groups, and are surrounded by a kind of involucre formed either by the cohesion together of the youngest whorl of leaves, or by a perichætial outgrowth resembling that of Marchantia. They are produced directly from the apical cell or its youngest segments, so that they are terminal in their position. Usually each archegonium is protected also by a perigynium.

FIG. 869.

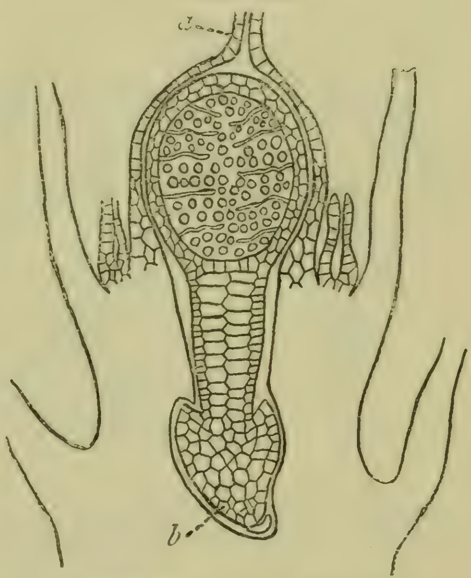


Fig. 869. Sporogonium of *Jungermannia*. *a.* Calyptra. *b.* False foot. After Sachs.

The histological differentiation of the shoot is very slight. The stem possesses an axial strand of cells which have thin walls, while the cortex is made up of fairly thick-walled cells. There is no indication of anything like vascular tissue. The leaves are simple plates of cells of uniform substance, being only one cell thick.

The sporophyte is mainly derived from the epibasal cell of the first division of the oospore, the hypobasal one often not developing at all, but remaining in an atrophied condition at the base of the stalk of the capsule. The epibasal mass then can be differentiated into the capsule and a bulky stalk or seta, the lower end of which swells and forms a false foot (*fig.* 869). The archesporium is co-extensive with the endothecium and produces spores and sterile cells, usually elaters. When it is

mature the capsule dehisces, sometimes regularly by valves, sometimes irregularly.

A calyptra is formed during the growth of the embryo or sporophyte, much as in Marchantia. When the capsule is mature, a rapid growth of the short seta ruptures it at the apex, and the sporogonium is exposed. It then dehisces as described.

According to Goebel, there is a possible link between the Hepaticæ and the Chlorophyceæ in the genus *Aneura*, from the thallus of which certain cells are liberated which may be compared with the zoospores of the latter. On liberation each divides into two cells, and ultimately gives rise to a new gametophyte. They differ from zoospores in not possessing cilia.

Class V.—MUSCI (MOSSES).

In the group of the true mosses a still further advance, especially in the direction of anatomical differentiation, is seen. The gametophyte is always foliose, and bears rhizoids instead of simple root hairs. The sporogonium escapes from the calyptra before the spores are mature; it never contains elaters, and always possesses a well-defined columella. The plants are of small size, and grow upon the earth, rocks, trees, or old walls; some are saprophytic, growing on decaying wood, &c. A few are aquatic.

Fig. 871.

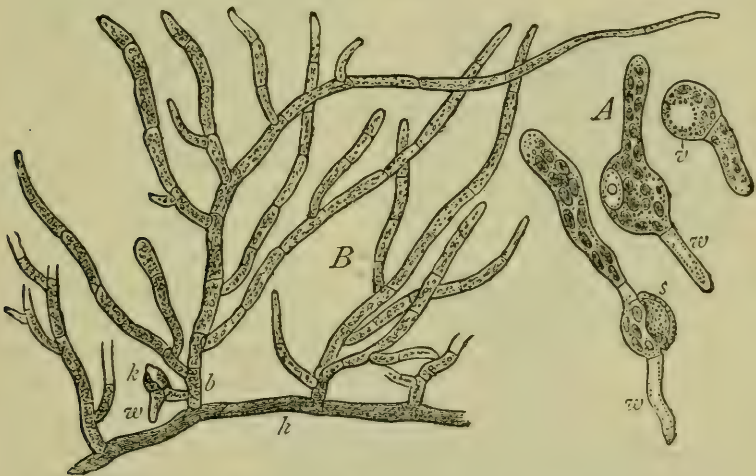


Fig. 870. Protonema of Moss. A. Early stages of germination of spore. B. Developed protonema on which young bud, *k w*, is formed, which will give rise to the moss plant. After Sachs.

The protonema is in most cases a filamentous structure, copiously branched. The septa are usually arranged obliquely across the filament. Generally part of it ramifies below the surface of the soil and is colourless, while the remainder contains chloroplastids. Each filament grows by segmentation of a single terminal or apical cell.

The shoot is rarely dorsiventral as in the Liverworts. It grows by means of an apical cell, which is usually three-sided, and gives rise by its segmentation to three rows of leaves. It is frequently branched, the branches arising not in the axils of the leaves, as in the Phanerogams, but either beside or below them.

The branching is usually monopodial, but sometimes cymose. From the base of the shoots a number of rhizoids spring and affix it to the substratum. The plant is not supplied with water exclusively by these, the leaves having the power of absorbing liquid.

The shoot is differentiated into stem and leaves. The anatomical structure of the stem is interesting as giving the first indication of a central stele, which, is, however, very rudimentary. The outer layers form a cortex of somewhat prosenchymatous cells with thick walls. This gradually passes into a thin-walled parenchyma. In some forms the axis is occupied by a strand of small rather thin-walled cells or tracheïds (*fig.* 872). In others there is a rudimentary vascular stele consisting of a number of cells, which are partly parenchymatous and partly prosenchymatous. The latter cells are tracheïds, as are those of the first type; true vessels are never developed. This central group of cells, partly thin-walled, partly thick-walled, corresponds to the xylem of the stele. It is often surrounded by elongated thin-walled cells, which correspond to phloëm. There is no pericycle and no endodermis.

FIG. 872.

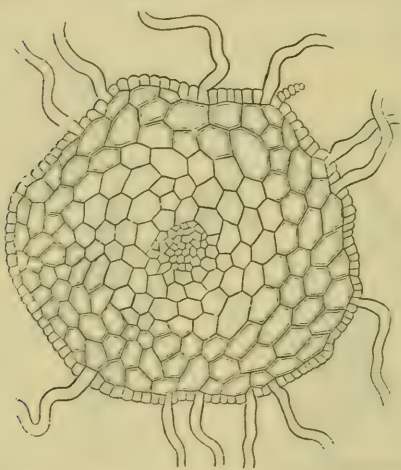


Fig. 872. Section of stem of gametophyte of Moss, showing central strand of thin-walled small cells, surrounded by large-celled cortex and epidermis. After Sachs.

The leaves which are developed on the stem are simple in most mosses, consisting often of a single layer of cells. Some forms are furnished with a midrib, chiefly composed of thick-walled cells almost prosenchymatous in shape. In some the midrib is penetrated by rudimentary vascular strands, which enter the stem and join its axial stele. The cells of the leaf all contain chloroplastids.

The leaves of the bog-mosses (Sphagnum) show a peculiarity in containing cells of two kinds (*fig.* 873); some are large, broad and almost lozenge-shaped, empty of contents, and marked by curious

spiral thickenings; others, which form a network between the large ones, are small and tubular and contain chloroplastids.

Fig. 873.

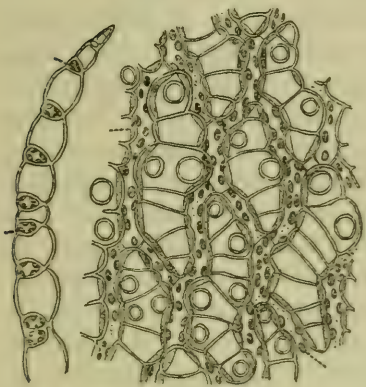


Fig. 873. Leaf of Sphagnum. A. Surface view. B. Section.

The antheridia and archegonia are usually borne amid clusters of leaves at the apex of a shoot. Most generally there are several together, though this is not always the case. Sometimes a shoot bears only antheridia, sometimes only archegonia, sometimes archegonia in the centre of the sorus or collection, and antheridia around the periphery. We may thus have monœcious, diœcious, or hermaphrodite arrangement.

The sorus is invested with leaves of rather different character from the ordinary foliage

Fig. 874.

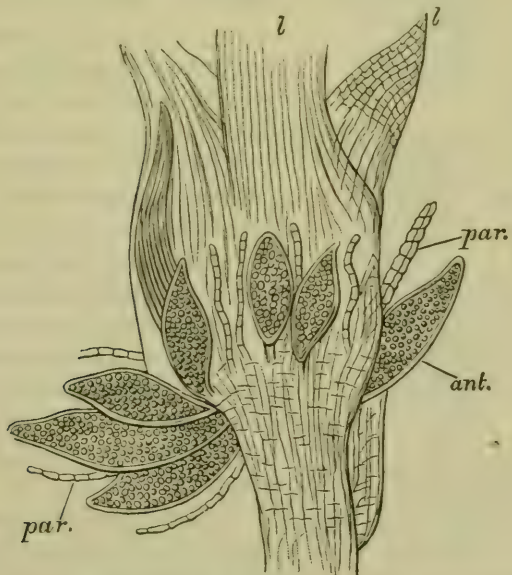


Fig. 874. Apex of fertile shoot of Moss (*Polytrichum*) bearing antheridia, *ant*, and paraphyses, *par*. *l*. Leaves of the shoot.

leaves; the innermost of them at any rate growing up in a sort of perichætial fashion round the base of the capsule as it begins

to develop. There is no special perichætium produced as in the liverworts.

Among the sexual organs are developed hairs of peculiar form known as *paraphyses*. These are multicellular, and often terminate in a globular head. They are singular in that their cells often contain chloroplastids.

Fig. 875.

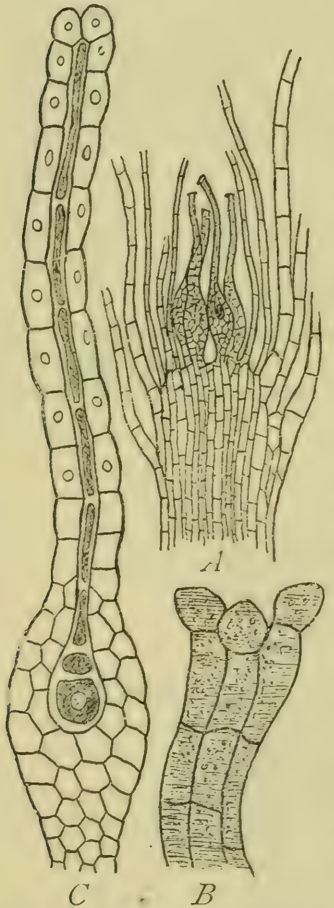


Fig. 875. A. Apex of shoot of Funaria with two archegonia. B. Neck of archegonium, showing mode of separation of the cells. C. Immature archegonium. After Sachs.

The antheridia differ but little from those of the Hepaticæ; they are club-shaped or rounded bodies, mounted on short stalks, and consist of a wall surrounding a cavity in which are the antherozoids. They open in the mosses by splitting across the apex. The mother cells of the antherozoids escape before emitting the antherozoids. They are attached to each other by a sort of intercellular mucilage derived from the cell-walls. This, however, dissolves as soon as it comes into contact with water.

The archegonia have the same general structure as those in the preceding group (*fig.* 875). There is a body or venter, and a long generally twisted neck. The body or venter is usually thicker than in the liverworts, and consists of two layers of cells. It contains, as in other cases, an oosphere, while the neck is filled with mucilage derived from the disintegration of its canal-cells and of the ventral canal-cell cut off in the formation of the oosphere.

The vegetative reproduction of the gametophyte is very varied. The chief feature of it is the ease with which almost any part of the plant can produce protonemal filaments, even root hairs doing so if exposed to light in a moist atmosphere. Similar outgrowths may spring from the rhizoids, or from the leaves, or from

the summits of the shoots which produce the reproductive organs.

Besides these protonemal outgrowths leaf-buds are sometimes formed which become detached and grow at once into moss plants. They may arise on different parts of the plant, but seem to be most easily developed upon root hairs. Some mosses multiply by the separation of branches, or by the production of stolons.

Definite gemmæ like those in the Marchantiaceæ are also of frequent occurrence. They are stalked flattened bodies of more or less circular shape, and consist of a single layer of cells. Many of them are developed together at the end of a long supporting axis in *Aulocomnion androgynum* (*fig.* 876); in *Tetraphis pellucida* they are produced in a terminal cup, which is composed of several leaves. When detached from the plant and transported to moist soil they germinate, putting out a protonema, on which a new gametophyte arises by the formation of a lateral bud.

It is in the structure and development of the sporogonium that the mosses chiefly show a great advance upon the liverworts. A sporogonium typical of most mosses is that of *Funaria hygrometrica*, the structure of which may be examined in some detail.

The first division of the oosphere is, as before, caused by the appearance of the basal wall, dividing it into epibasal and hypobasal segments. The latter takes little part in the subsequent development, not dividing more than once in most cases. In some of the less highly organised mosses, such as Sphagnum, it gives rise to a foot, but this absorbing organ in the higher forms is developed from the end of the seta.

The segmentation of the epibasal cell into octants is unusual. Instead, by a succession of oblique divisions, an apical cell is soon produced, and by the repeated division of this the embryo grows. When it has reached a fair degree of development, being fusiform in shape, the upper end swells to form the *capsule* or *theca*, and the remainder continues elongating to form the stalk or *seta*. As it elongates it ruptures the tissue of the archegonial wall which still surrounds it. This breaks across irregularly, and the withered neck with part of the venter-wall is carried up by the elongating stalk and is recognised as an easily detachable cap over the capsule. It is called the *calyptra*(*fig.* 877, B *o*).

When the capsule has become slightly swollen the tissue of its substance differentiates into amphithecium and endothecium.

An air space or cavity arises in the former, which extends in a cylindrical fashion all round the capsule, being crossed by strands or filaments of cells forming a number of bridles.

The endothecium gives rise to the archesporium, its outer layer being transformed into it. The remainder of its tissue, consisting of large cells, forms the columella. The archesporium is cylindrical and does not extend across the top of the columella. The walls of the capsule contain chloroplasts.

The arrangements for causing and regulating the escape of

FIG. 876.

FIG. 877.

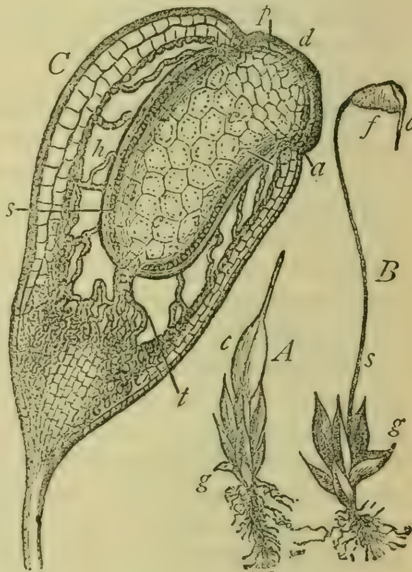


Fig. 876. A. *Aulocomnion androgynum*, showing gemmæ borne upon a long stalk. B. Collection of gemmæ more magnified.——*Fig.* 877. *Funaria hygrometrica*. A. Young sporogonium. *c.* Capsule. B. Adult condition of the gametophyte. *s.* Stalk or seta of the sporogonium. *f.* Capsule or theca. *o.* Ca'yptra. *c.* Section of a sporogonium × 80. *d.* Operculum. *p.* Peristome. *h.* Air space. *s.* Sporogenous layer. After Sachs.

the spores from the capsule are the *operculum* and the *peristome*. The former is the apical portion of the amphithecium. It is detached from the rest of the capsule by the swelling of the walls of a ring of epidermal cells, the *annulus*, situated at the point of rupture. This swelling causes the separation of the operculum from the rest of the theca, and the lid falls off.

The peristome is also developed from the amphithecium just below the operculum, so that when the latter falls off it forms a kind of fringe round the margin of the opening. The cells of

the innermost amphithecial layer, situated just above the termination of the cylindrical air-chamber, undergo thickening and cuticularisation on their external and internal faces. The lateral and part of the transverse walls connecting the others remain unchanged. These, as the peristome dries, break away from the cuticularised walls, and the latter separate longitudinally into several strips (*fig.* 878). There are thus two rows of cuticularised membranous teeth formed, which, so long as the operculum is in position, curve over and meet at a point in the centre. The outer ones are known as the *teeth* of the peristome, the inner ones, which are less strongly thickened, are called *cilia*. The number of teeth varies from 4 to 64, according to the number of longitudinal divisions of the cells. When the operculum falls off, these teeth uncoil in virtue of their elasticity and remain as a kind of fringe round the opening.

The base of the capsule below the air-space is slightly dilated, forming a mass of cells known as the *apophysis*. This is furnished with stomata, and contains a large amount of assimilating tissue.

FIG. 878.

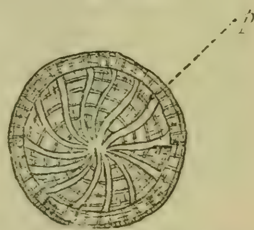


Fig. 878. Surface view of peristome, *p*, of Funaria.

There is a good deal of variety in the formation of the peristome in different genera. In some, as *Gymnostomum*, none is developed. In *Tetraphis* the layer giving rise to it is two cells in thickness, and all their walls become thickened, forming a plate of tissue. When this is released it splits into four valves or segments. In Polytrichum the development is different. The teeth are formed not of simple pieces of membrane, but of bundles of thick prosenchymatous cells. A plate of cells unites the top of the teeth and remains after dehiscence of the theca as a structure called the *epiphragm*.

As the spores mature the rest of the contents of the capsule dry up and shrink; when they are ripe nearly everything else has disappeared, so that the spores lie loose in the cavity of the theca.

Some species show important differences of structure from the type of Funaria. In Sphagnum the archesporium which is developed from the inner layer of the amphithecium is a hemispherical or dome-shaped band extending across the top of the capsule and covering the columella. In Polytrichum a second air-chamber is formed in the endothecium on the inner side of the archesporium. In a few mosses there is no operculum.

The advance in histological differentiation which marks the gametophyte is also seen in the structure of the sporophyte. There is a well-marked epidermis furnished with rudimentary stomata. The seta contains a strand of pseudo-vascular tissue similar to that described as occurring in the stem. The tissue of the sporogonium also contains chloroplastids.

The phenomenon of *apospory*, which is not uncommon in

FIG. 879.

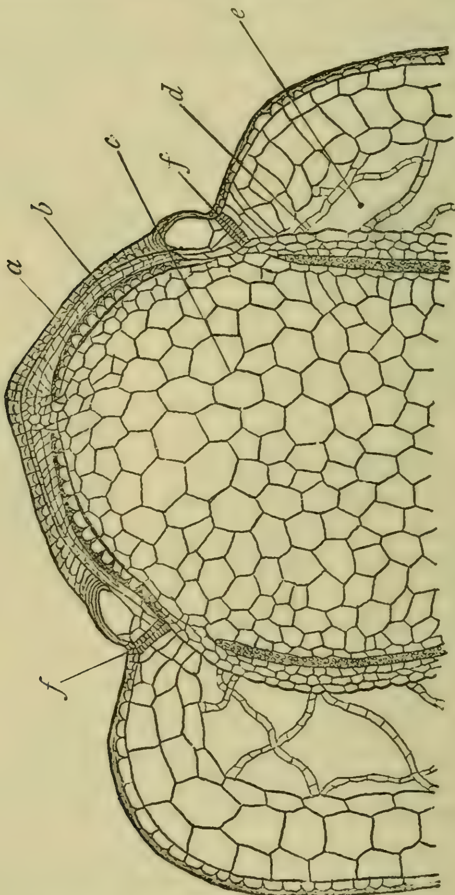


Fig. 879. Upper portion of capsule (sporogonium) of *Funaria* × 50. *a.* Operculum. *b.* Peristome. *c.* Columella. *d.* Sporogenous tissue. *e.* Air-chamber. *f.* Cells forming the rim of the capsule after the operculum has been detached. The cells just above these form the annulus.

the next group, the Pteridophyta, occurs also in some mosses. Under favourable conditions some of the cells of the sporogonium put out protonemal filaments which give rise by budding to new gametophytes. We get thus the formation of the latter from the sporophyte without the production of spores. This may be taken as a case of vegetative reproduction, which we have seen to be so common in the gametophyte generation.

CHAPTER V.

Group III.

PTERIDOPHYTA.

This group, which is sometimes known as the group of the Vascular Cryptogams, includes the Ferns, the Equisetums or Horsetails, and the Lycopodinæ or Club-mosses. They are called *Vascular* Cryptogams, to indicate that their tissues contain well-differentiated vascular structures, which we have seen to be almost entirely unrepresented in the preceding two groups. The life history embraces two phases, as in the case of the Bryophyta, but the order of their greater prominence is reversed. The gametophyte is small, cellular, and usually of very short duration; the sporophyte forms what is commonly called 'the plant,' and may persist for many years. It shows considerable morphological and histological differentiation.

Comparing the group with that of the Bryophyta we note especially the retrogression in size of the gametophyte, and the great advance made by the sporophyte. Further, that the sporophyte does not remain all its life parasitic on the gametophyte, but that it develops roots and leaves, and soon becomes independent of the latter, which usually perishes as soon as the sporophyte becomes well established. The latter generally persists many years, producing its spores annually.

In describing the forms which are included in the group, it is well to begin with the sporophyte on account of this predominance.

It shows considerable morphological differentiation, possessing, with few exceptions, root and shoot, the latter consisting of stem and leaves. The stem is often of considerable size; its growth may be sub-aerial, but it frequently takes the form of a rhizome.

The leaves are of very various sizes; in the ferns as a rule they are large and compound; in the club-mosses much smaller and more numerous; in the horsetails reduced to scales closely

surrounding the stem. They are of two kinds ; some are ordinary foliage or scale leaves ; others bear sporangia, and are known as sporophylls, as in the higher plants. In the ferns there is usually no difference between the two, but in the other groups the sporophylls are often much modified. In the Equisetinæ and some of the Lycopodinæ they are collected together at the apices of special shoots, forming cones or flowers.

The sporophylls bear the sporangia usually in clusters, known as sori, which may be exposed to the air, or variously covered in for purposes of protection. In some cases the sporangia arise directly from the stem in the axil of the sporophyll. In the ferns and horsetails the sporangia are on the under or dorsal surface ; in the club-mosses on the upper one.

The primary roots are shortlived, soon being replaced by adventitious secondary ones. *Salvinia* has no primary or secondary roots, nor, so far as we know, have some species of the isosporous ferns and some of the club-mosses.

A peculiar feature makes its appearance in the Pteridophyta, which persists throughout all the higher plants. This is the production by the sporophyte of two kinds of spore, each of which gives rise to its appropriate gametophyte. The two kinds of spore differ from each other chiefly in size, some, called *microspores*, being very small, and others, *macrospores*, much larger. Each is produced in its appropriate sporangium, so that we distinguish *micro-* and *macrosporangia*. The peculiarity of producing both kinds is called *heterospory* ; we speak thus of *isosporous* and *heterosporous* Vascular Cryptogams.

It some cases all the sporangia of a sorus are closely attached together as if coherent. They are so developed, never being free from each other. The resulting body appears like a multilocular sporangium, but it is better to regard it as compound and call it a *synangium*.

A similar multilocular appearance is afforded by the sporangia of *Isoetes*, but in this case it is due to bands of the archesporial tissue becoming sterile, and crossing the sporangium in the form of a number of trabeculæ.

Sporangia are classed in two categories, according to the manner of their development. In some plants, as in many ferns, they arise each from a single superficial cell. These are known as *leptosporangiate* forms. In others, as in the *Marattias* and *Isoetes*, the sporangia arise from a group of cells of the superficial and sometimes deeper layers as well. These forms are called *eusporangiate*.

The anatomical differentiation of the sporophyte shows a great advance on that of the sporogonium of the Bryophyta. The epidermal and cortical or fundamental tissue systems are

FIG. 880.

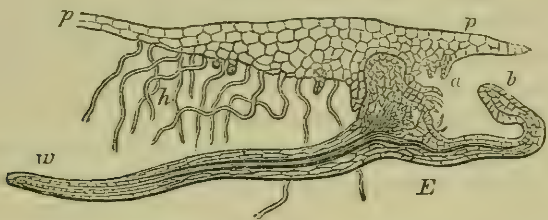


Fig. 880. Section through prothallium, *p p*, and young fern plant. E. The latter attached to the former by the foot. *a*. Archegonia of the prothallium. *h*. Root hairs of same. After Sachs.

clearly distinguishable, and the axis is either mono-, schizo- or polystelic. The stele consists of xylem and phloëm, in vascular bundles, with circumferential pericycle in most cases. There is often a very marked development of sclerenchyma either in bands or patches. The leaves range from very simple structures to others almost as well differentiated as the leaves of Phanerogams; but their mesophyll is not so well divided into palisade and spongy parenchyma, and the epidermal cells contain chloroplastids.

The growth in length of the stem, root, and leaf is usually effected by the segmentation of apical cells. In some cases, instead of a single apical cell there is a group of them, especially in the higher forms, where we have indicated an approach to the Phanerogams. Growth in thickness of the axis rarely takes place; there is, however, a modified cambium in *Isoetes* and in some of the *Ophioglossaceæ*. Some of the fossil forms of this group showed considerable cambial activity, the axis becoming of very considerable diameter.

FIG. 881.

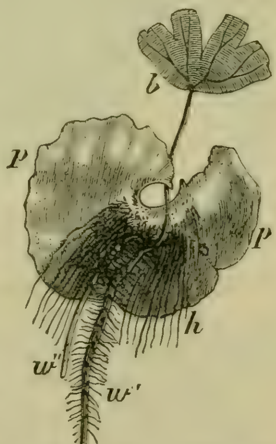


Fig. 881. Prothallium, *p*, *p*, of *Adiantum Capillus-Veneris* seen from below, showing the Fern-plant developed from the fertilised germ-cell of the archegonium. *b*. First frond. *w*,' *w*.'' Roots. *h*. Root hairs. After Sachs.

The secondary roots are not developed from the pericycle, but from the *endodermis* of the axis; in the horsetails from its

inner layer. They thus originate in the periblem and not in the plerome.

The growth of the sporophyte from the oospore or zygote shows considerable variety. Epibasal and hypobasal segments are produced, as in the Bryophyta, by the formation of a basal wall. In the ferns and horsetails this is followed by segmentation into octants. From the epibasal octants the stem and either one or two primary leaves or cotyledons are then produced, while from the hypobasal ones proceed the primary root, and a foot which, as in the Bryophytes, serves to attach the sporophyte to the tissue of the gametophyte (*figs.* 880 and 881). The foot is

Fig. 882.

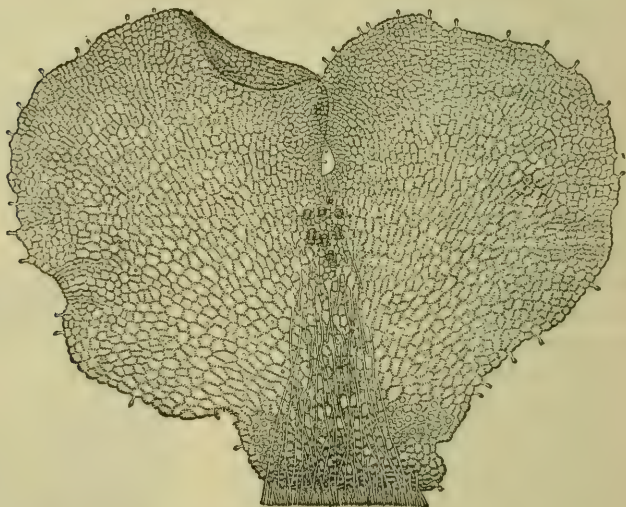


Fig. 882. Prothallium (gametophyte) of Fern. After Kny.

in this group a transitory structure, which perishes as soon as the sporophyte is capable of an independent existence. In the club-mosses the hypobasal segment gives rise to a *suspensor*, as it does in Phanerogams (page 184). This is only composed of a single cell, or a chain of a few cells in length.

The gametophyte arises from the germination of the spore, in most cases becoming free from it (*fig.* 882), but in certain cases remaining partly or almost entirely in its cavity (*fig.* 883). In the former case it is usually a small thallus composed only of cells and containing chloroplastids. Its morphological character is, however, varied; it may be a filamentous much-branched body, somewhat recalling a protonema, or it may be tuberous

and fleshy (*fig.* 917, *p*), when it is developed underground and contains no chlorophyll. It is always known as the *prothallium.*

In the heteroporous forms there are two kinds of prothallia formed, one from the microspore, and the other from the macrospore. In neither case do we get the prothallium entirely set free from the spore. They are not very strongly developed, only sufficiently so indeed to permit of the production of the sexual organs. The prothallium from the microspore gives rise to antheridia; that from the macrospore to archegonia. In some of the isosporous forms the prothallia, which are all alike as to their vegetative features, are monœcious, producing both antheridia and archegonia; in others, as in the equisetums, they are diœcious, only bearing one or other of them.

FIG. 883.

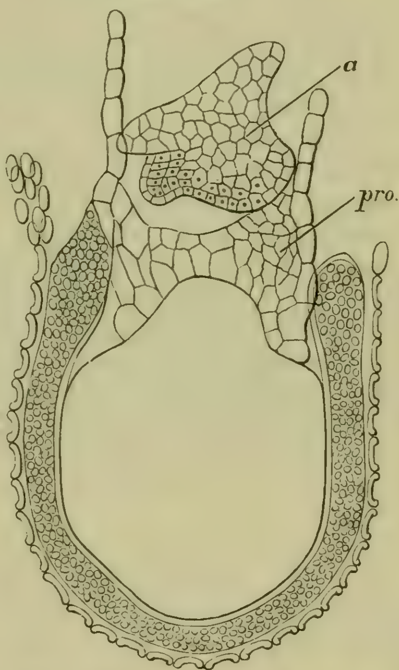


Fig. 883. Gametophyte produced by the macrospore of *Salvinia. pro.* Prothallium bearing *a*, young sporophyte. After Pringsheim.

The antheridia are either immersed in the substance of the prothallium, as in the tuberous forms, or project from the surface as in the flattened ones. They are superficial always in their origin, and consist of a wall of a single layer of cells, which encloses a number of spirally coiled ciliated antherozoids (*fig.* 860, B). The archegonia are also superficial, having a venter embedded in the tissue of the prothallium, and a slightly projecting neck consisting of only a small number of cells (*fig.* 897). The structure is otherwise like that of the Bryophytes. Fertilisation is effected in the same way as in the latter group. The number of archegonia produced often depends upon whether or no the oospheres of the first-formed ones become fertilised. If not, others are developed.

Vegetative reproduction of the gametophyte is not uncommon

it takes place by means of gemmæ, or by branches which become detached. Similar reproduction of the sporophyte is brought about by the development of adventitious buds, arising on either the petiole or the lamina of the leaf in many ferns. In some of the equisetums some of the underground shoots form tubers, which may remain dormant for some time and ultimately produce new stems. A similar formation is found in some of the club-mosses.

The phenomenon of apospory is not infrequent. A specially interesting form of it occurs in *Athyrium Filix-fœmina*, where sporangia produced in the normal position grow out into prothallia instead of forming spores. In other cases the prothallia spring from the tips of the pinnæ of the leaves.

The converse process, the production of a sporophyte from the prothallium without the formation of an oospore, is occasionally seen. The prothallium in this case sometimes produces sterile archegonia; sometimes none at all. The sporophyte in either case arises as an adventitious bud upon it. This phenomenon is known as *apogamy*.

The Pteridophyta are usually arranged in three groups or series, being thought to have arisen by separate lines of development from a common Bryophytic ancestor. These three classes are the Filicinæ, the Equisetinæ, and the Lycopodinæ.

Class VI.—FILICINÆ.

The usual classification of the forms included in this class is as under :—

Sub-Class Isosporeæ.—One kind of spore only is produced ; on germination it gives rise to a free prothallium.

Section 1. *Leptosporangiatæ.*—Each sporangium is produced from a single epidermal cell.

This section includes most of the Ferns proper.

Section 2. *Eusporangiatæ.*—Each sporangium arises from a group of epidermal cells.

This section includes the Ophioglossaceæ and Marattiaceæ.

Sub-Class Heterosporeæ.—The spores are of two kinds, microspores and macrospores or megaspores. The prothallia do not become free from the spores on germination. The microspore produces a prothallium bearing an antheridium, the macrospore develops one bearing archegonia. Neither form of prothallium is ever free from the spore.

Section 1. *Leptosporangiatæ.*—Each sporangium arises from a single epidermal cell.

This section includes the water ferns, Hydropterideæ, sometimes called the Rhizocarps.

Some botanists place a second section here to include the Isoetaceæ, which are eusporangiate. They are, however, generally included among the Lycopodinæ.

Section 1.—Isosporous Leptosporangiate Ferns.

The sporophyte of this group is the plant usually termed a Fern. It has generally a conspicuous body, morphologically differentiated into stem, roots, and leaves.

The stem is usually a creeping underground rhizome, though in some cases it is borne upon the surface of a tree, and in others, as in the tree ferns, it grows vertically into the air. It usually gives off a number of adventitious roots and bears a

relatively few large, often pinnate, leaves. In some ferns the stem branches normally, the branch system being lateral and not dichotomous as in the lower groups; in others the branching is

Fig. 884.

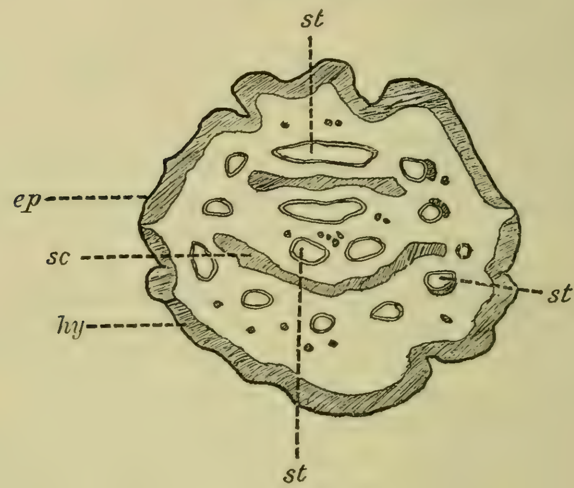


Fig. 885.

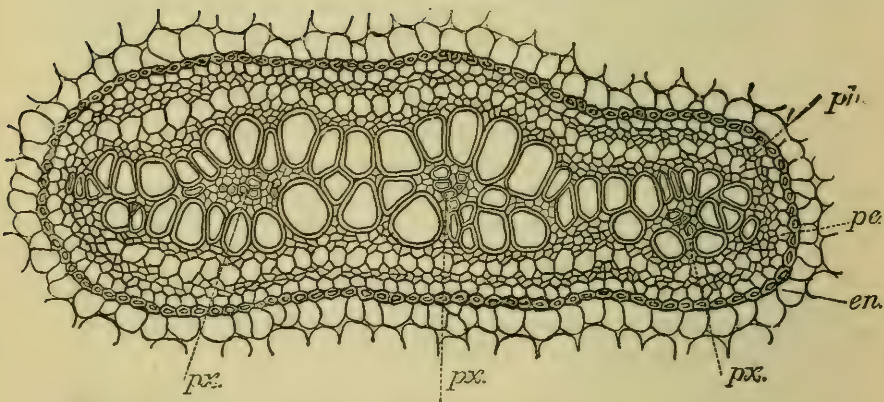


Fig. 884. Polystelic stem of Fern. *st.* Steles. *sc.* Bands of sclerenchyma. *hy.* Hypodermal sclerenchyma. *ep.* Epidermis.——*Fig.* 885. Stele of stem of Fern, composed of three fused concentric bundles. *en.* Endodermis. *pe.* Pericyle. *ph.* Phloëm. *px.* Groups of protoxylem.

adventitious. The roots are always adventitious, for though a primary root is always developed it never persists in the adult fern. The adventitious roots are small and often branched, arising in great numbers from the stem or the leaf stalks. The

leaves are sometimes of three kinds, the *foliage leaves*, sometimes entire, but usually much and repeatedly pinnate; the *sporophylls*, which in many ferns are exactly like the foliage leaves in appearance, but in others are much modified; and *scaly leaves*, rarely found, and then only on subterranean rhizomes. The vernation of the leaves is very markedly *circinate*, the main axis and all its branches or pinnæ emerging from the earth rolled up with their lower surfaces outwards. The stem and bases of the leaf stalks are furnished when young with numerous scaly hairs, called *ramenta*, which are multicellular and sometimes glandular.

The growth in length of the stem is always brought about by the divisions of a pyramidal apical cell of either two or three sides, the apex of the pyramid being directed inwards. It soon shows a differentiation into dermatogen, periblem, and plerome. At first the stem is always monostelic, but this condition in most cases soon gives way to polystely, which persists throughout its length (*fig*. 884). The separate steles are usually gamodesmic, the bundles of which they are composed being completely united together, presenting the appearance of a central mass of wood with two or three strands of protoxylem, almost surrounded by bast, though not entirely, as the latter does not wrap round the narrow end of the woody mass. The whole is enclosed by a pericycle and an endodermis, the latter belonging to the fundamental tissue (*fig*. 885). Sometimes a stele will consist only of a single bundle (*fig*. 886), though generally fusion takes place. The steles as viewed in longitudinal section of the stem, or better, as isolated by maceration, are found to anastomose together very irregularly, forming a meshwork, from the angles of which branches go off to enter the leaves. The nature of the anastomosis is largely determined by the number and size of the leaves.

The bundles are said to be concentric. As they are usually placed two or three together in the stele and fused laterally, this is not very apparent, the whole stele seeming rather to deserve this name, the fused bast masses surrounding the fused wood masses. A single bundle, however, when found free (*fig*. 886), is seen to be concentric; and a stele is usually composed of two or more placed so close together that the bast is not developed on their contiguous faces. The lateral fusion of bast and wood of the original bundles thus gives rise to the mass of wood in the stele with its peripheral envelope of bast. The steles should perhaps be called bi-collateral rather than concentric, as the bast is not

continuous round the narrow ends of the wood masses (*fig.* 885).

The monostelic arrangement persists in a few families (*Osmundaceæ*, *Hymenophyllaceæ*, &c.); the bundles in the stele are then sometimes collateral.

The pericycle is absent from the stele of some of the Polypodiaceæ, being then replaced by an inner layer of the endodermis, as in the root of Equisetum.

The stem of the fern is usually well supplied with sclerenchyma, which is developed in various forms in the ground

Fig. 886.

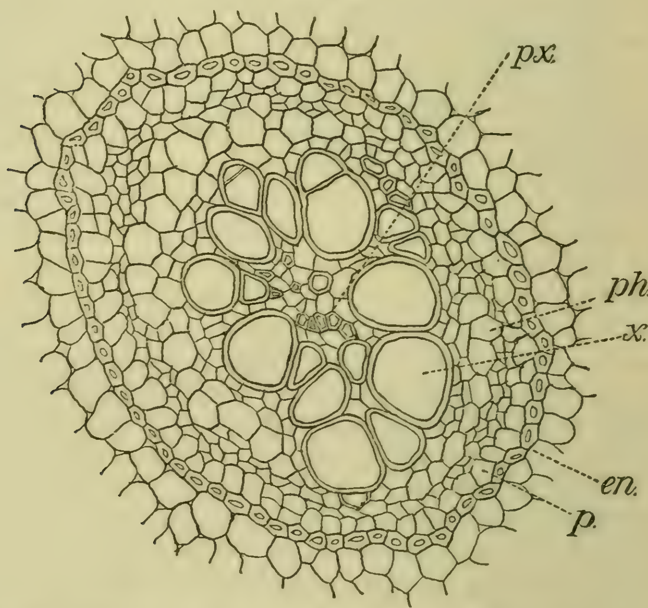


Fig. 886. Concentric bundle from Fern stem. *en.* Endodermis. *p.* Pericycle. *ph.* Phloëm. *px.* Protoxylem. *x.* Xylem.

tissue. It is often found as a strong hypodermal sheath, deep brown in colour, and consisting of several layers of cells with very greatly thickened walls. Isolated bands of greater or less extent are common in the inner part of the ground substance (*fig.* 884).

The tissue of the wood and bast is generally characteristic. The wood is chiefly made up of large tracheïds thickened in a scalariform manner. True vessels are rare, and there is not much wood parenchyma. The sieve-tubes of the bast (*fig.* 887)

are long, narrow tubes with bluntly pointed ends, and have their sieve-plates more or less regularly arranged along their whole length, being thus marked out into very characteristic areas. They have no companion-cells and no callus.

Except in the monostelic stems the bundles are cauline. They are always closed, cambium not being present.

FIG. 887.

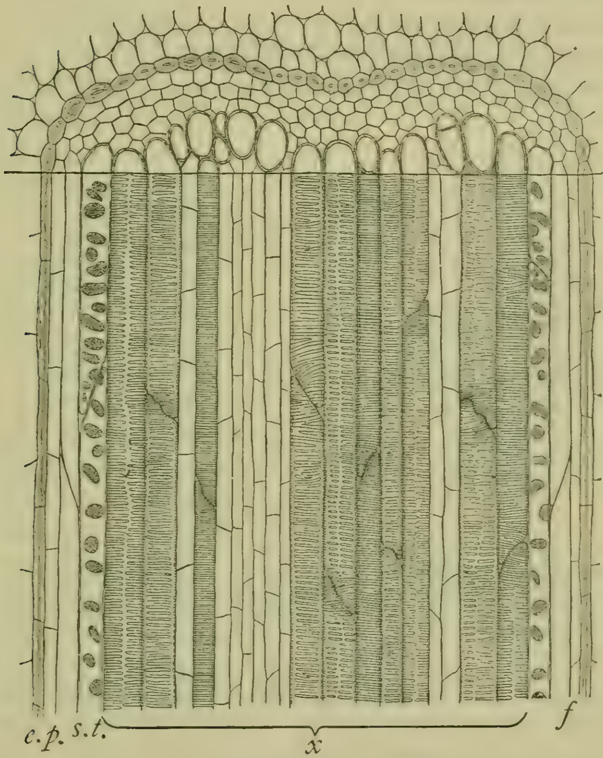


Fig. 887. Section of stele of Fern. The upper part is transverse, the lower longitudinal. *e.* Endodermis. *p.* Pericycle. *s. t.* Sieve-tube. *x.* Xylem. *f.* Fibres of bast.

The primary root is in all cases developed, but it usually soon perishes, and its work is taken over by adventitious roots which are produced in great numbers from the stem or the leaf-stalks. Each originates in the endodermis of one of the steles, opposite to a xylem bundle. By the formation of two walls a pyramidal apical cell is cut out of one of the cells of the endodermis, and by successive divisions it gives rise to the

adventitious root, which grows out through the fundamental tissue in the way already described (*fig.* 888). Occasionally, as in *Osmunda*, there may be a group of initial cells at the apex, instead of the usual pyramidal one.

The root is monostelic, the stele containing sometimes two, sometimes three bundles; the pericycle may consist of a single layer of cells or of many, and sometimes it is irregular, being one layer of cells thick in part of its course and more than one layer thick in the remainder.

When the roots branch the new root springs from the old one in the same way as the latter did from the stem.

The foliage leaves arise each from a single superficial cell of the growing point of the stem. They grow in most cases by means of a two-sided apical cell. In vernation they are strongly curled up owing to the greater growth of the under surface. Later the region of growth changes to the upper surface and the leaves expand. In structure they resemble the leaves of Angiosperms, but the differentiation of the mesophyll into palisade and spongy parenchyma is not so well marked. The epidermal cells as a rule contain chloroplastids. The vascular cylinder is generally monostelic in the petiole, but becomes schizostelic in the leaf blade. The stele joins one of the steles of the stem as already described.

Fig. 888.

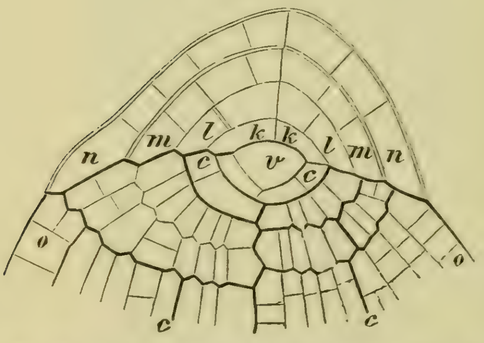


Fig. 888. Longitudinal section through root of *Pteris hastata*, showing apical region. *v*. Apical cell, from which are developed the tissue of the substance of the root, *o*, *c*, and the root-cap, *k*, *l*, *m*, *n*. After Sachs.

In some Ferns the sporangia are borne upon leaves that cannot be distinguished in appearance from ordinary foliage leaves. In others, as in *Osmunda*, *Aneimia*, &c., there are definite, specialised sporophylls. These show various shapes, the pinnæ generally being narrower than those of the foliage leaves. In the most specialised, the upper or lower branches of the phyllopodium are scarcely at all winged, the edges being covered by clusters of sporangia.

The sporangia occur usually in groups on the lower or dorsal surface of the sporophylls (*fig.* 890), or in some cases in a band along their margins, being situated on a kind of placental outgrowth. They are sometimes quite exposed to the air, sometimes partially protected by hairs or paraphyses which arise among them from the placenta. Generally, however, the sorus is more or less covered by a definite membrane called the *indusium*, which springs from the epidermis of the leaf. Where the sorus is marginal, as in *Pteris*, the edge of the leaf curves over it, forming a false indusium, which sometimes is supplemented by a kind of membrane springing from the leaf along the inner side of the sorus.

Fig. 889.

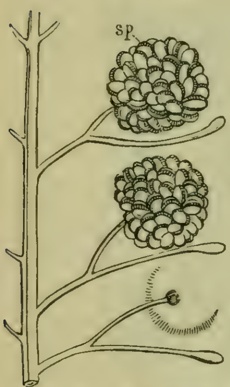


Fig. 890.

Fig. 891.

Fig. 889. A portion of a frond of the common Polypody (*Polypodium vulgare*), showing two sori springing from its veins. The sori are naked, and consist of a number of sporangia or capsules, *sp*, in which the spores are contained.——*Fig.* 890. Portion of a frond of the Male-fern (*Aspidium Filix-mas*), with two sori, *s*, *s*, covered by an indusium.——*Fig.* 891. Portion of a frond of the Royal or Flowering-fern (*Osmunda regalis*), with its sporangia or capsules arranged in a spiked manner on a branched rachis.

The sorus (*fig.* 892) consists of a number of sporangia, often mixed with a number of hairs or paraphyses, which are sometimes glandular. Each sporangium is an ovoid or globular body placed upon a long stalk. It originates from a single superficial cell of the placenta, which grows outwards and becomes divided into two. The upper one gives rise to the body of the sporangium, the lower one to the stalk. As the upper one grows, there are formed in it three oblique walls, which cut out of it a somewhat tetrahedral cell with its base uppermost. A further wall is formed across its base, so that the structure consists of a wall and a central cell. Divisions parallel to the

first ones cut off from the latter four protective cells which form the *tapetum*, an investing nutritive layer, which by subsequent divisions of its cells becomes multicellular. The central cell so formed is the *archesporium*.

Changes now take place in both inner and outer parts of the growing organ. The four peripheral cells undergo repeated division by anticlinal walls, so that the outer coating of the sporangium becomes multicellular, remaining one cell thick. A special band of cells forming part of this wall, running in some cases longitudinally and in some obliquely or transversely, becomes peculiarly thickened, as in *fig*. 892, and constitutes the *annulus*.

FIG. 892.

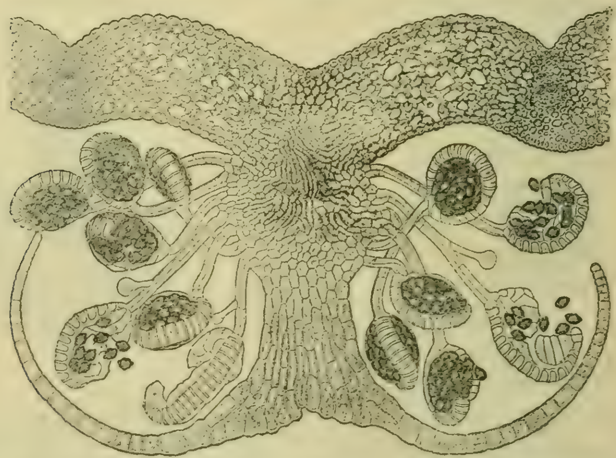


Fig. 892. Section of sorus of Fern, consisting of a number of *sporangia* borne upon a placental outgrowth from the under side of the leaf and covered by an *indusium*. Each sporangium has running nearly round it a row of thick-walled cells, the *annulus*. After Kny.

Its walls are strongly cuticularised, more so than the walls of the rest of the cells, which, however, undergo cuticularisation to some extent. The annulus in most cases does not extend completely round the sporangium, but leaves a few thin-walled cells between itself and the stalk, which cells form the *stomium*, where eventually the sporangium opens. The tapetum becomes multicellular and for a time invests the archesporium, its cells being filled with very granular protoplasm. The archesporium divides repeatedly till it consists of sixteen cells, which are the mother cells of the spores. When this stage is reached, the tapetal cells become disorganised and give rise to a mucilaginous fluid in

which the archesporial mass remains. Each mother cell then divides by free-cell formation into four cells, usually but not always arranged at the four angles of a tetrahedron, so that the resulting cells are pyramidal in form. Each undergoes rejuvenescence and surrounds itself with a new cell-wall, forming a spore. The walls of the original mother cells then disintegrate as did those of the tapetum, and the spores, sixty-four in number, lie free in the cavity of the sporangium. The development is shown in *fig.* 893.

In some cases the stalks of the sporangia are not developed,

Fig. 893.

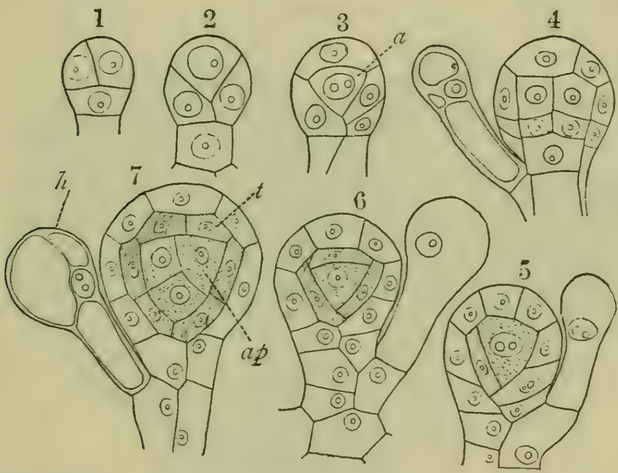


Fig. 893. Development of the sporangium of the Fern. The figures indicate the successive stages. *a.* Archesporium. *t.* Tapetum. *ap.* Sporogenous tissue. After Kny.

so that those organs are sessile; in others the stalk gives rise to a glandular hair (*fig.* 893, 7 *h*).

When the sporangium is ripe, the drying of the cells of the annulus leads to great tension in the stomium, which ruptures, and the annulus recoils with some force, scattering the spores.

In the Tree ferns the annulus extends all round the sporangium, so that it includes the stomium.

Different genera show a certain variety in the position of the annulus, and consequently in the direction of the rupture. The dehiscence is, however, brought about in a similar manner in all.

The gametophyte in the Ferns is always a thallus, having

no differentiation into members. It is known as the *prothallium*, and is usually a green flattened expansion of small size. Its cells contain chloroplastids. From the under side a number of root hairs are developed which attach it to the soil.

Sometimes the prothallium has a central somewhat thickened portion known as the *cushion*. Sometimes it is almost filamentous, recalling the protonema of a moss.

It always becomes quite free from the spore.

On the under side of the prothallium the sexual organs are developed, the antheridia lying to the basal end and the

FIG. 894.

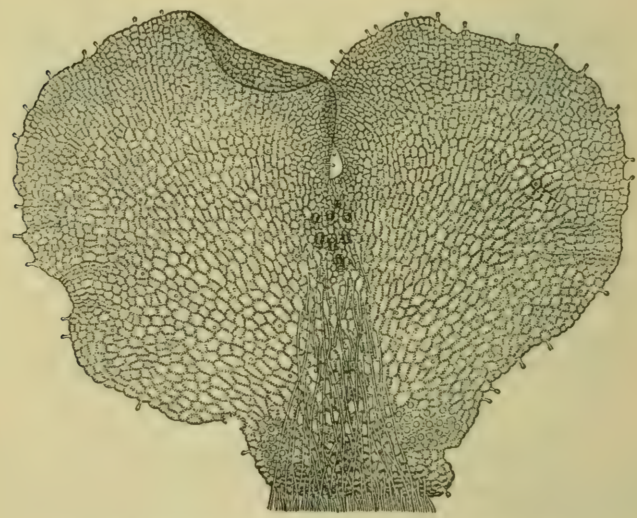


Fig. 894. Prothallus (gametophyte) of Fern. After Kny.

archegonia, which are formed later, towards the anterior or apical region. In a few cases a prothallium develops only one or other of the sexual organs, but generally both are to be found in the relative positions described.

When the spore germinates, the outer coat ruptures and the inner one grows out into a green filament consisting of a single row of cells (*fig*. 895, 1–4). The end cell of the row soon divides longitudinally, and the plate-like prothallium becomes recognisable. The growth is soon continued by the formation of an apical cell (*fig*. 895, 5), which after a while is found to lie in a sort of notch or depression in the anterior margin.

The cushion is formed by the cells in the middle line in the anterior region then dividing in a plane parallel to the surface so that the mass becomes several cells in thickness there. This cushion bears the archegonia and may in a way be compared to the archegoniophore of the liverworts. The antheridia do not arise on the cushion, but towards the posterior margin.

The *antheridium* is always superficial in origin (*fig.* 896). An epidermal cell grows out and is divided into two, the upper one of which produces the organ. It divides into two cells, the lower of which forms a stalk-cell. The upper one divides repeatedly, so as to form a wall surrounding a central cell, in which the mother cells of the antherozoids are produced by repeated cell-divisions. In each mother cell a single antherozoid is produced, which is a coiled filament furnished with cilia at its anterior end (*fig.* 860, B). When the antheridium is mature it ruptures, and the mother cells, containing the antherozoids, escape, the antherozoids being liberated a little later. The whole of the protoplasm of the mother cell is not used up to form the antherozoid, so that when the latter escapes it has usually attached to it a vesicle of protoplasm, the rest of the contents of the mother cell.

Fig. 895.

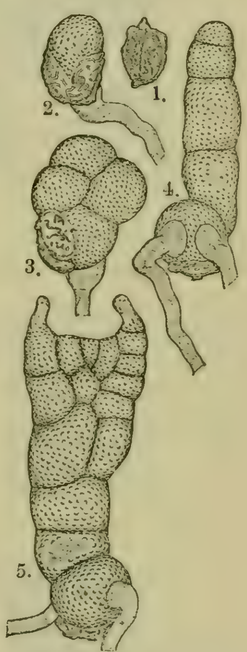


Fig. 895. 1–5. Successive stages in the early development of the prothallus (gametophyte) of the Fern. After Kny.

The development of the archegonium (*fig.* 897) is also from a superficial cell of the prothallium, which segments into two, an upper and a lower. The neck is derived from the former by a succession of divisions. It is much like the neck of the archegonium of the moss, but much shorter, consisting of only a few tiers of cells. The lower cell grows upwards into the neck, separating its cells somewhat and forming the neck-canal-cell, which remains single. The neck-canal-cell is cut off from the remainder, which then constitutes the *central cell* of the archegonium. This next cuts off a small *ventral-canal-cell*, and the remainder rounds itself off into an ovoid mass of protoplasm, which is the *oosphere*.

Later the ventral-canal-cell and the neck-canal-cell become

mucilaginous, and the neck of the archegonium opens by the separation of its cells.

Fertilisation is effected by the entry of an antherozoid into the neck of the archegonium and its ultimate fusion with the oosphere at its base. The mucilaginous matter ejected from

FIG. 896.

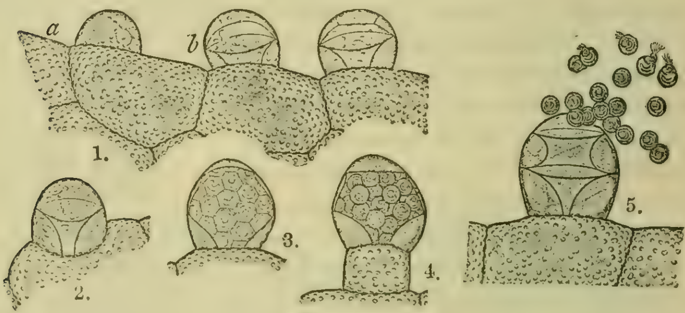


FIG. 897.

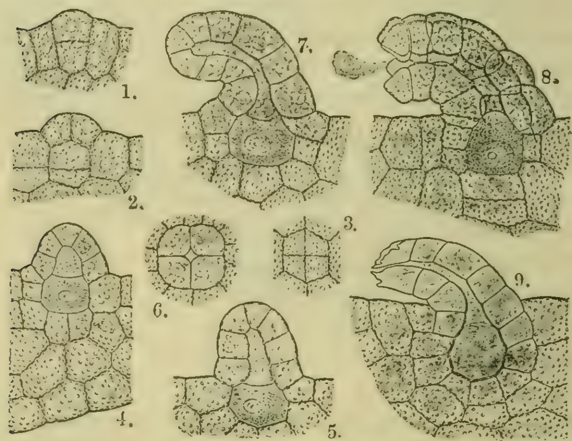


Fig. 896. 1–3. Development of the antheridium of the Fern. 5. Antherozoids escaping. After Kny.——*Fig.* 897. Development of archegonium in the Fern. The figures indicate successive stages. 3 and 6 are transverse sections of the neck in two stages. After Kny.

the archegonium is said to contain a substance, probably malic acid, which has an attraction for the antherozoid, enabling the latter to find its way to the canal of the neck.

When fertilisation has been effected the oosphere clothes itself with a cell-wall, and becomes the *zygote*, or *oospore*. It

is soon segmented into epibasal and hypobasal parts by the formation of a basal wall parallel to the axis of the archegonium. Each gives rise by further divisions to four octants. In further development the epibasal octants give origin to the stem and first leaf, or cotyledon, of the young sporophyte ; the hypobasal ones form the primary root and a special organ, called the *foot*, which attaches the young fern to the prothallium, from which it draws a supply of nutrient material. The foot becomes a somewhat bulky structure and occupies the space formed by the venter of the archegonium (*fig.* 880).

The primary root soon disappears ; the cotyledon also lasts but a short time, and is succeeded by the foliage leaves, arising from the stem. The foot also disappears as soon as the young fern has become capable of absorbing its nutriment from its environment independently of the gametophyte.

The prothallium seldom lives longer than is necessary to produce a single sporophyte. The sporophyte, on the contrary, may produce spores for many years, each being able to give rise to a gametophyte. Sometimes the gametophyte lives longer, in some cases for more than a year.

The vegetative reproduction of ferns occurs in both generations. The gametophyte may give rise to branches or to gemmæ, either of which can develop into prothallia. The sporophyll may produce adventitious buds, generally on the petioles of its leaves where they are below the soil.

Both apospory and apogamy may occur in this group.

Section 2.—Isosporous Eusporangiate Ferns.

In this section are comprised two orders of Ferns, the Ophioglossaceæ and the Marattiaceæ, which have much in common with the previous group, but differ in that their sporangia are derived each from a group of superficial cells instead of from a single one.

Ophioglossaceæ.

The affinities of the Ophioglossaceæ have lately been much discussed, and many doubts have been suggested as to their being properly included among the ferns, certain points in their structure suggesting an affinity with the Lycopodinæ. For the present, however, it will be well to give them their old position.

The sporophyte is generally a short erect rhizome bearing a few leaves which are not circinate in vernation. Generally

only one appears above ground each year. Between this leaf and the apex of the stem the rudiments of four other leaves may generally be found, so that it takes five years for a leaf to attain its full development.

The sporangia are borne upon a peculiar outgrowth from the ventral surface of the petiole of the sporophyll, which has the appearance of being branched, one branch bearing an ordinary foliage lamina and the other an elongated, sometimes branched, spike-like structure, embedded in or placed upon which are the sporangia, arranged in two rows, one on each side of its axis, or variously clustered upon its surface (*fig.* 898).

The stem is very short and presents some peculiar features in its interior. There is usually present none of the sclerenchyma, so characteristic of the Ferns; the arrangement of the vascular structures is different also, the Ophioglossaceæ being schizostelic and the bundles of the steles being collateral. Ophioglossum itself has no pericyle in its steles. The genera *Botrychium* and *Helminthostachys* possess cambium in their collateral bundles,

Fig. 898.

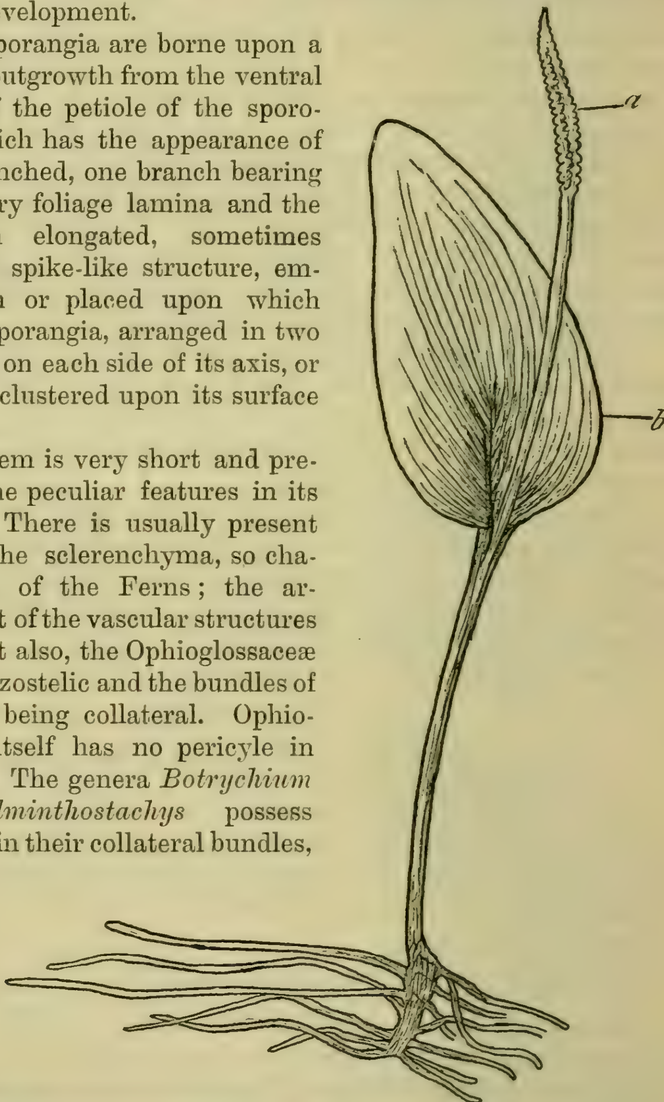


Fig. 898. *Ophioglossum vulgatum.* *a.* Sporangia. *b.* Foliage leaf.

but it does not give rise to much secondary tissue. Cork also occurs in the cortex of these stems.

The sporangia, situated as described above, are usually quite independent of each other, not being arranged in sori. They are often embedded in the tissue of the sporophyll and open when ripe by valves or slits. Each contains numerous spores.

The gametophyte is best known in *Ophioglossum pedunculosum* and *Botrychium Lunaria.* In the former it is a tuberous body growing underground and devoid of chloroplastids. From it springs a cylindrical gametophore, which grows up through the earth and becomes green. It bears antheridia and archegonia. In the latter it is again tuberous and subterranean; it has root hairs, and bears antheridia and archegonia, the latter being chiefly on its lower and the former on its upper surface.

Marattiaceae.

The stem of the sporophyte, as in the last case, is generally a rhizome, which is sometimes branched, and bears numerous

Fig. 899.

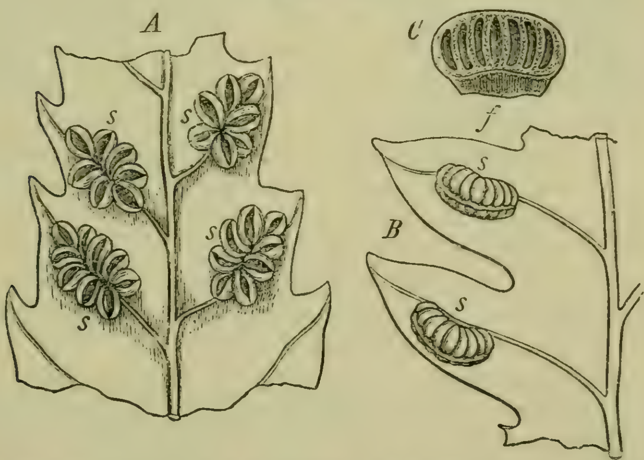


Fig. 899. Synangia, *s*, of A, Angiopteris, B, Marattia; C, section of synangium of B. After Sachs.

leaves. The latter resemble those of the true ferns, from which they differ by bearing well-marked stipules. The roots branch considerably, the branching being lateral.

The histology of the stem recalls that of the true ferns, the arrangement of the vascular tissue being polystelic, and the bundles of the steles concentric. There is more variety in regard

to the sclerenchyma, which is never very prominent and is in some cases absent. Gum passages of probably schizogenous origin are found in many parts.

The sporangia are arranged in sori, but the several sporangia of each sorus are coherent instead of being developed separately. They thus form a body, at first sight suggesting a compound sporangium. This is known as a *synangium*. They are filled with numerous spores and dehisce when ripe by a slit or an apical pore (*fig.* 899).

The gametophyte is a flattened green prothallium, much like that of the true ferns. It has a cushion in the centre, on which both antheridia and archegonia are borne. It grows by an apical cell. The sexual organs have the same structure as in the ferns.

SECTION 3.—HETEROSPOROUS LEPTOSPORANGIATE FERNS. (*Rhizocarps* or *Hydropterideæ.*)

This group, which has much in common with the isosporous ferns, introduces a difference which becomes more and more important as we go higher and higher in the scale. The plants bear spores of two kinds, the *microspores* and the *macrospores* or *megaspores*. Each of these in turn produces a special form of gametophyte, and those which are derived from the macrospores never become free from the spore, being largely developed in its interior. As we pass upwards from this point this peculiarity becomes more and more marked, until we find the prothallium always completely endosporous. The great importance of this is seen in that it leads ultimately to the production of the body known as the *seed*, which is the distinguishing feature of Phanerogamic plants.

The Hydropterideæ or Rhizocarps were till comparatively recent times considered as a separate group. It is usual now to include them with the Ferns, to which they show considerable resemblance. They are all of aquatic habit, and are hence named *Hydropterideæ*. The group comprises four genera, *Salvinia*, *Azolla*, *Pilularia*, and *Marsilea*, which according to the arrangement of their sporangia are divided into the two orders *Salviniaceæ* and *Marsileaceæ*. Salvinia and Azolla float freely upon the surface of water; each has a horizontal rhizome, sometimes copiously branched. Upon the rhizome are borne numerous leaves arranged in rows, which in Azolla are all alike, but in Salvinia are of two kinds, floating and submerged.

Azolla bears numerous adventitious roots; Salvinia is altogether rootless.

In Salvinia the phyllotaxis is whorled, three leaves being produced at each node. Of these, two are broad, somewhat rugose, entire floating leaves, placed opposite each other. The third is divided into a number of filamentous branches which hang down freely into the water (*fig.* 900) and function as roots. In Azolla the leaves are alternate and are arranged in two rows on the upper surface of the rhizome. Each leaf is two-lobed, one lobe floating while the other is submerged. Pilularia and Marsilea have perennial rhizomes and are attached to the substratum. They are found in bogs or marshes. From the

FIG. 900.

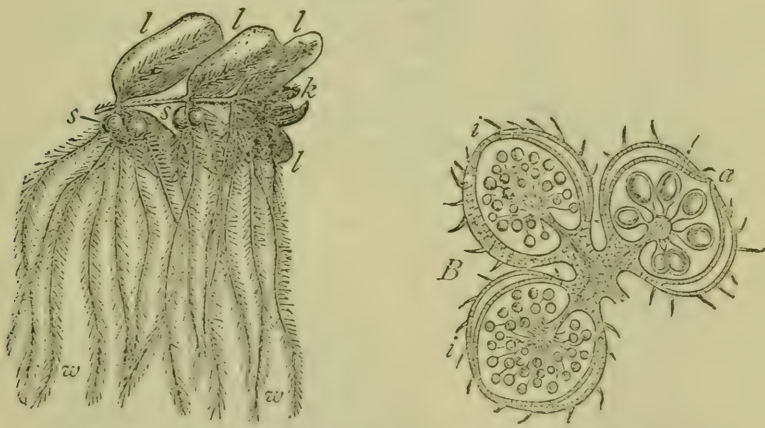


Fig. 900. Part of a plant of Salvinia. *l*. Floating leaves. *w*. Submerged leaves. *s*. Sori. *k*. Apex of stem. B. Longitudinal section through three sori of Salvinia. *i*, *i*. Two with microsporangia. *a*. One with macrosporangia. After Sachs.

rhizome the leaves grow vertically upwards, being arranged alternately on the stem. In the former genus the leaf is unbranched and somewhat cylindrical; in the latter it is compound, bearing four leaflets at the end of a long petiole (*figs.* 901, 903).

Both Pilularia and Marsilea produce adventitious roots from the rhizome.

In Salvinia and Azolla the stem is monostelic, the stele being of very small dimensions. It is not furnished with a pericycle, but is surrounded by a two-layered endodermis. In the other genera the stem is at first polystelic, but eventually becomes gamostelic from the fusion of the separate steles to form a ring (*fig.* 902). This ring encloses some fundamental tissue which simulates a

pith. It can be distinguished from the latter by the fact that there is an endodermal band on both sides of the ring of bundles. The bundles are concentric in all four genera. The fundamental tissue contains large intercellular spaces or lacunæ.

The growth in length of both stem and root is carried on by means of an apical cell, which is either two-sided or tetrahedral.

A curious feature of the leaf of Azolla is the occurrence of a pit or cavity in the tissue of the dorsal lobe in which small colonies of Nostoc filaments are found, much as in Anthoceros. This is a case of symbiosis, as in the latter plant.

The two orders Salviniaceæ and Marsileaceæ differ from each other in the arrangement of their sporangia. They agree in having them placed in

FIG. 901.

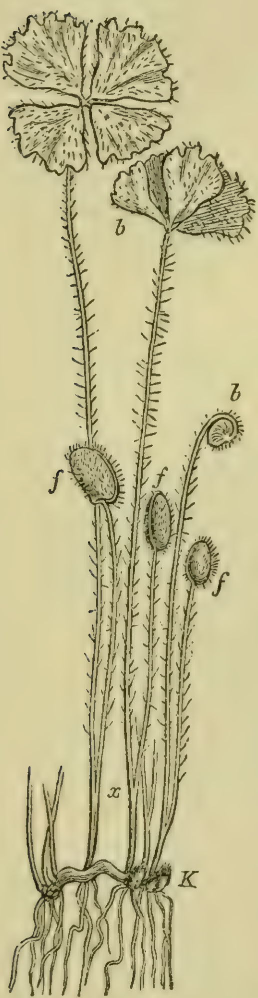


FIG. 902.

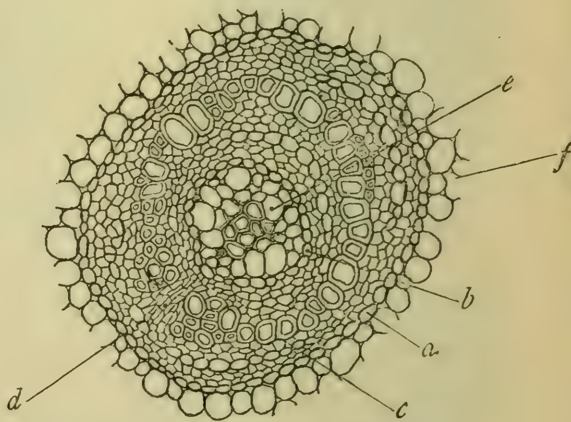


Fig. 901. Plant of Marsilea. K. Rhizome. *b.* Leaves. *f.* Sporocarps springing from the leaf stalks at *x*. After Sachs.——*Fig.* 902. Stele of Marsilea, showing gamostelic structure. *a.* Outer endodermis. *b.* Inner endodermis. *c.* Fused xylem bundles. *d.* A point at which the fusion does not extend to the wood. *e.* Fundamental tissue isolated by the fusion of the steles. *f.* Cortex.

curious globular or ovoid bodies, which occur in Salvinia and Azolla on the submerged leaves or lobes of leaves; in Marsilea

on stalks springing from the petioles of the leaves much as in Ophioglossum ; and in Pilularia from the rhizome on the ventral side of a leaf.

In Salvinia and Azolla, the two genera of the Salviniaceæ, the structure is a sorus of sporangia, covered in by a cup-shaped indusium, which differs from the corresponding structure in the ferns by being composed of two layers of cells, separated in Salvinia by an air space (*fig.* 900, B), and by completely closing over the sorus. In Azolla the walls of the upper part of the indusium become lignified. At the base of the globular chamber so formed there is a cellular placenta, from which the sporangia spring. Each sorus consists either of microsporangia or macrosporangia, but never contains both. The number of microsporangia in a sorus in both genera is considerable. The macrosporangia are less numerous, the sorus of Salvinia containing not more than twenty-five, while that of Azolla contains only a single one.

FIG. 903.

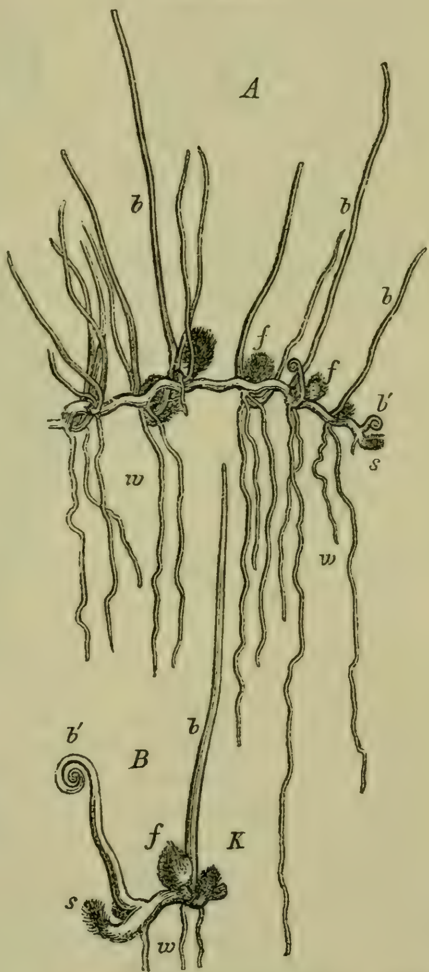


Fig. 903. *Pilularia globulifera.* A. Natural size. B. End of shoot (enlarged). *s.* Apex of stem. *b.* Leaves. *w.* Roots. *f.* Sporocarps.

In the Marsileaceæ (Pilularia and Marsilea) the sporangia are borne in a complex structure known as a sporocarp. This is a modified leaf-branch, as shown in *fig.* 901. It is an oval or globular body with a very hard wall ; its interior is divided into a number of chambers, each of which contains a sorus. The sori

contain both micro- and macrosporangia. In Marsilea there is in each a single row of the latter in the middle, and a double row of the former on each side of it. In Pilularia the arrangement is not so definite.

The sporocarp is made to rupture by the mucilaginous character of the internal tissue, which absorbs water and causes the wall of the sporocarp to split. In Pilularia the rupture begins at the apex, in Marsilea it takes place along the side. In the sporocarp of the latter is a band or ring of mucilaginous tissue, to which the walls of the chambers containing the sori are attached. When the sporocarp ruptures by the swelling of this ring, the latter protrudes through the opening, and still swelling drags out with it the sori in a kind of string or chain (*fig.* 905, B C). When free from the sporocarp the walls of the sori-chambers and those of the sporangia disintegrate, setting free the spores.

Fig. 904.

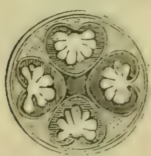


Fig. 904. Transverse section of the sporocarp of *Pilularia globulifera.* After Henfrey.

Fig. 905.

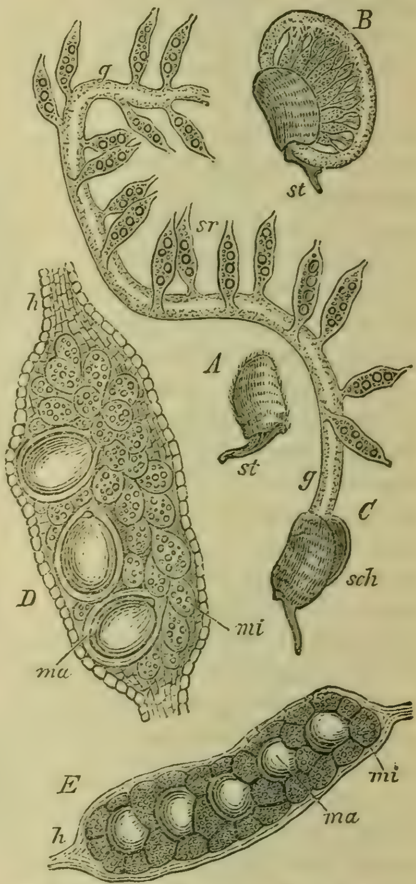


Fig. 905. *Marsilea salvatrix.* A. A sporocarp (natural size). B. A sporocarp which has burst its water and is protruding its gelatinous ring. After Hanstein. C. The ring ruptured and extended, showing the separated sori, *sr*. D. A sorus showing macrosporangia and microsporangia. E. A sorus from a ripe sporocarp. After Sachs.

The spores in this group of plants are characteristic. Instead of possessing only two walls and lying free in the sporangia, as

in almost all other cases, they either have a third coat, derived from the epiplasm of the disorganised tapetal cells, or they are by this epiplasm agglutinated together into one or more spore masses. The conditions differ in the different genera. In Salvinia all the microspores of a sporangium are fastened together; in Azolla there are from two to eight of such masses in a sporangium, each being known as a *massula.* A delicate skin surrounds each massula, and this in some species is furnished with a number of hairs bearing barbed processes, known as *glochidia*, at their free ends. In the Marsileaceæ the microspores are free from each other, but each is coated by its *epispore* or *perinium*, derived from the tapetal epiplasm.

In Salvinia, Pilularia, and Marsilea the macrospores are similarly invested, but each one is free. The outer layer of the epispore in the last two genera is capable of swelling enormously on being wetted, surrounding the apex of the spore with a mucilaginous coating.

In Azolla the epispore on the lower surface of the macrospore is developed into large spongy masses which serve as floats, enabling it to drift about after partially escaping from the sporangium. The upper surface is firmer and bears filamentous outgrowths. The apex of the spore is generally furnished with a number of delicate filaments extending between the floats. The glochidia of the massulæ of microspores generally catch in these filaments, so that the massulæ are anchored to the macrospore.

The microspores are not set free from the microsporangium in Salvinia, but germinate *in situ.* In Azolla the separate massulæ escape and float about in the water, those that have glochidia usually becoming entangled in the filaments developed from the perinium of the macrospore.

The gametophyte in this group shows considerable reduction when compared with that of the ferns. The heterospory, as already pointed out, involves the production of two kinds of gametophyte, one from each kind of spore. We have from the microspore one that bears only male organs, *antheridia*, and from the macrospore one that bears only female organs, *archegonia.* In neither case does the gametophyte become entirely free from the spore which gives it origin; in some cases a good part of it remains enclosed within the spore.

In Salvinia the microspores germinate by putting out a tubular protrusion of the endospore, which pierces the mucilaginous matter in which they are embedded and makes its way

through the wall of the sporangium. It then forms a septum at the end, cutting off a terminal cell which later divides into two. The tube constitutes the prothallium, and its two end cells after further divisions form a rudimentary antheridium, in which are produced four antherozoids (*fig.* 906).

When the antherozoids are mature, the antheridium ruptures as in other cases, and the antherozoids, each in its mother-cell, escape into the water. Only part of the protoplasm of the mother-cell is used in the formation of the antherozoid, as in the ferns.

Azolla produces a similar male gametophyte. In the Marsileaceæ the latter is formed within the microspore. The first division of the spore produces a small basal vegetative cell and a larger apical one, which forms an antheridium. By successive divisions this comes to consist of eight cells surrounded by a parietal layer or wall. The central cells produce each four antherozoids. Throughout the group the male prothallium is destitute of chloroplastids.

Fig. 906.

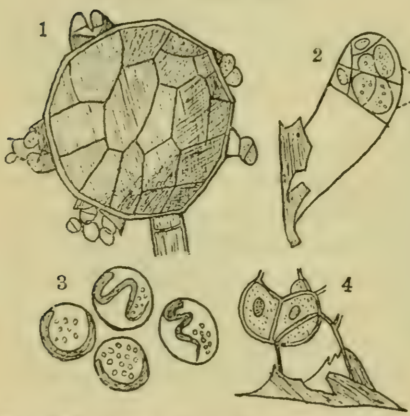


Fig. 906. Germination of microspores of *Salvinia*. After Sachs. 1. The mass of spores putting out tubular prothalli. 2. A prothallus, with antheridium, *a*. 3. Antherozoids in mother-cells. 4. Ruptured antheridium.

The formation of the female prothallium is a good deal alike in all the genera, showing small differences in the extent of its protrusion from the spore, from which it is never free. The macrospore begins to germinate before its coats rupture; it first cuts off a small cell at its anterior end or apex, by a wall known as the *diaphragm*, which thus divides the spore into two. The small cell at the apex continues to divide, forming a small celled tissue which soon protrudes through the spore-coats, owing to the rupture of the latter. The emerging tissue develops chloroplastids and becomes green; it constitutes the prothallium. In Salvinia it is somewhat triangular in shape and bears two winged appendages (*fig.* 907). In the Marsileaceæ only a small part of it protrudes from the opening of the spore.

The lower cell takes no part in the formation of the prothallium, but remains almost unchanged, becoming filled with various reserve materials for the nutrition of the young embryo developed later on the prothallium. In Azolla its nucleus divides repeatedly, but no cell-walls are formed in it.

The archegonia are developed at the apex of the prothallium, three being usually formed in Salvinia, but only one in the Marsileaceæ and Azolla. If none of the first formed ones become fertilised, more are developed later. The structure is similar to that of the ferns.

In the germination of the zygote or oospore Salvinia shows some peculiar features. It segments into octants as in the Ferns, but all the hypobasal cells go to form the foot. No root is developed. The first leaf or cotyledon, developed from two of the epibasal cells, is of curious shape. It is known as the scutiform leaf. In the other three genera there are two cotyledons, stem, and root, as well as foot.

Fig. 907.

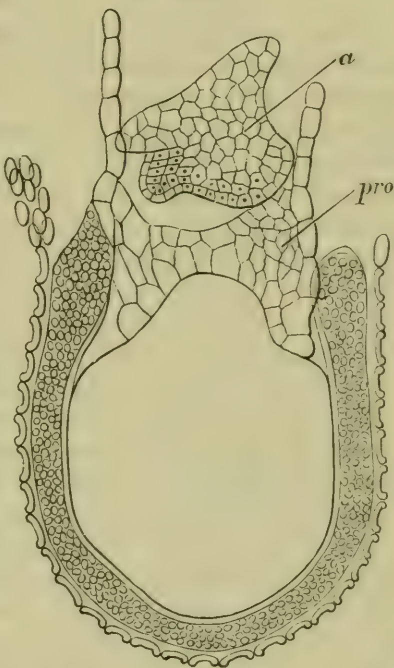


Fig. 907. Gametophyte produced by the macrospore of *Salvinia*. *pro.* Prothallium bearing *a*, young sporophyte. After Pringsheim.

Class VII.—EQUISETINÆ.

The plants included in this class, which only includes the genus Equisetum, are characterised by a peculiar habit; they generally have a much-branched subterranean rhizome, from which sub-aerial shoots are given off which rise erect and may attain a height of six or seven feet. These aerial shoots are of two kinds, one purely vegetative and the other ultimately becoming terminated by a cone-like collection of sporophylls, forming a flower. The shoots are surrounded at every node by a ring of small scale-like leaves cohering together at their bases, in the axil of each of which a branch is produced, causing a succession of whorls of branches to appear. Each of these has the same structure as the stem from which it arises (*fig.* 909).

The roots are adventitious and are produced from the nodes of both rhizome and sub-aerial stem. In the former case they grow into elongated structures, but in the latter they remain rudimentary and never grow out from the tissue of the stem.

In a few species the flowering shoot is different from the form described above; it either does not produce branches, or very few occur upon it, or they are not developed till the spores are shed. In one or two cases the sub-aerial shoot, whether sterile or fertile, remains almost or quite unbranched.

The green colour of the plant is due to the stem, the leaves being brown and scaly.

The sporophylls are gathered together at the apex of the fertile shoot, and they form a conical mass which may properly be considered as a flower. Its structure is a thin cylindrical axis on which a number of peltate leaves are arranged close together in a succession of whorls. Each leaf or sporophyll consists of a thick flattened head, to the centre of which a stalk is attached at right angles. On that side of the peltate head or blade which is turned towards the axis, there are a number of sessile sporangia. Each leaf may bear from five to ten, all of which contain numerous spores (*fig.* 908).

Just below the flower there is a ring of curiously modified leaves, forming what is known as the *annulus*.

Equisetum grows by means of an apical cell, as do the ferns. Such a cell is to be found at the apex of stem, branch, and root (*fig.* 910).

A transverse section of the rhizome, taken a little way from the growing point, shows its exterior divided into ridges and furrows. Opposite to each furrow there is, a little way from the surface, a large lysigenous intercellular cavity. These together are known as *vallecular* cavities. They are interrupted at the nodes, where a sheet of parenchymatous tissue stretches across them.

FIG. 908.

FIG. 909.

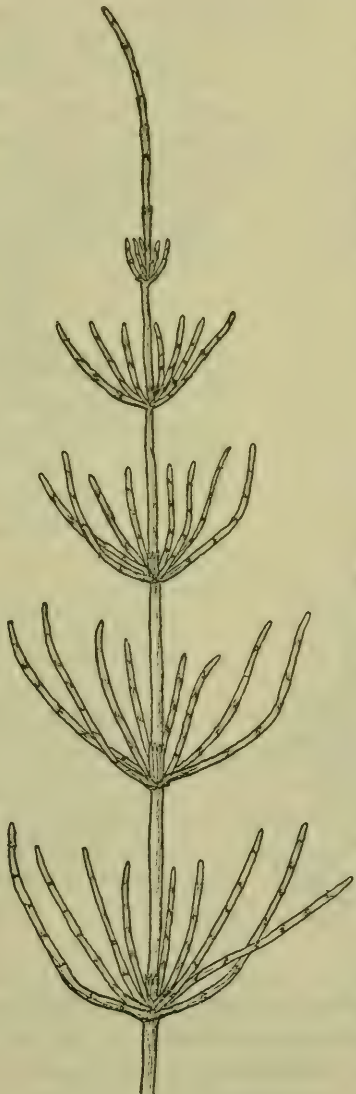


Fig. 908. Fertile stem of *Equisetum* bearing a flower or cluster of sporophylls.——*Fig.* 909. Sterile shoot of Equisetum.

FIG. 910.

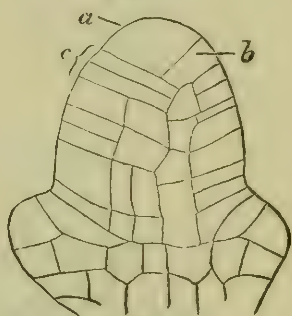


Fig. 910. Growing point of shoot of *Equisetum arvense*. × 250. *a*. Apical cell. *b*, *c*. Successive segments cut off from it.

A little internal to these cavities are the several steles, the plant being schizostelic. These are arranged differently in different species, and we may distinguish three varieties. In *E. litorale* (*fig.* 911, A), the steles are all separate, each is clothed with peri-

cycle and endodermis, and they are arranged in a ring round the stem. In *E. silvaticum* the separate steles fuse together laterally, forming a gamodesmic mass. The pericycle and endodermis are then absent from the sides of the steles, and the portions remaining behind and in front of each stele fuse together, form-

FIG. 911.

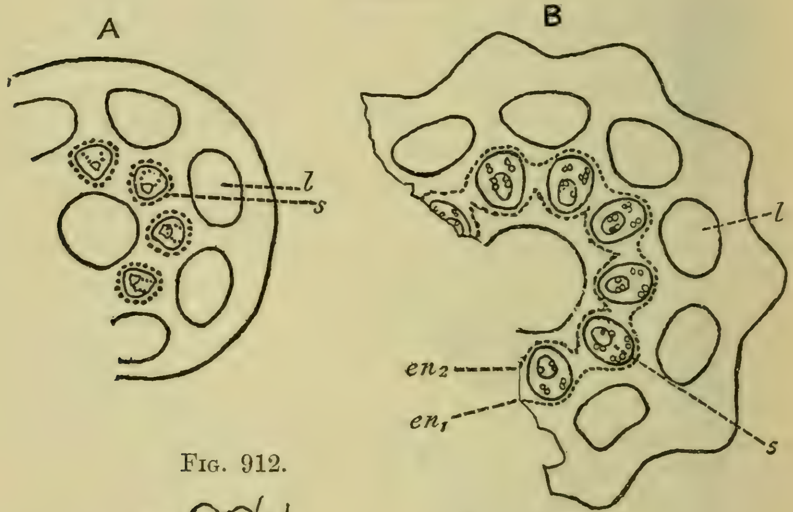


FIG. 912.

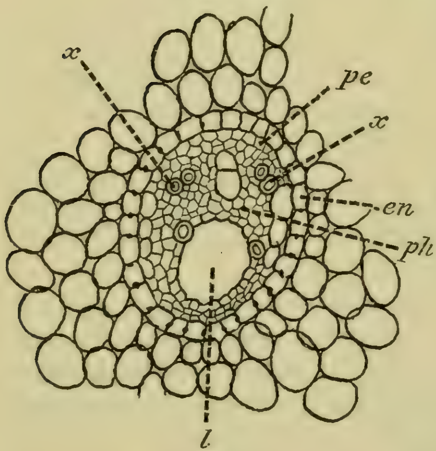


Fig. 911. Diagram of stem in two species of *Equisetum*. A. *E. litorale*. *s*. The separate bundles or schizosteles, each with its endodermis. B. *E. silvaticum*. The schizosteles, *s*, have their endodermis fused laterally. In both figures *l*= cortical lacunæ. After Pfitzer. ——*Fig.* 912. Section of vascular bundle of *Equisetum limosum*. *en*. Endodermis. *pe*. Pericycle. *x*. Xylem. *ph*. Phloëm. *l*. Lacuna. After Dippel.

ing two continuous bands, one surrounding the whole collection and the other forming an internal lining to it (*fig.* 911, B). In *E. palustre* the inner endodermal layer is not well marked, the cells not thickening in the same way as those of the outer. This rhizome appears to be monostelic, though it is not really so.

The centre of the rhizome is in most cases filled with paren-

chymatous tissue, forming a kind of pith. In some it is a large air-cavity.

There is considerable development of sclerenchyma just under the epidermis, forming a very strong hypoderma.

Each stele consists of a single closed collateral bundle, the wood of which is much reduced. Generally it consists of the protoxylem and two groups of tracheïds (*fig.* 912, *x*). In the region of the wood it contains always a conspicuous air space, the *carinal* cavity, into which the elements of the wood often protrude (*fig.* 912, *l*).

Fig. 913.

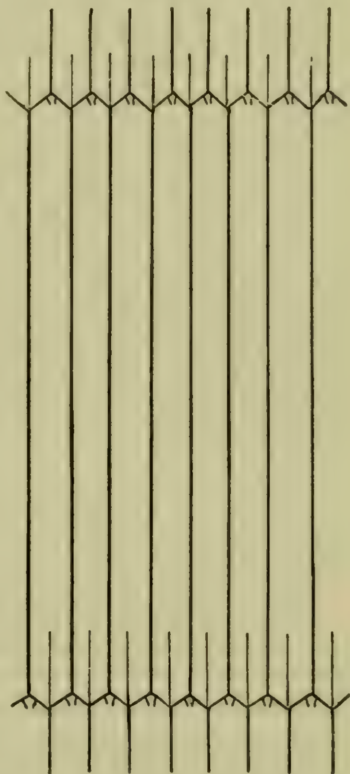


Fig. 913. Diagram of the course of the fibrovascular bundles of *Equisetum* through two nodes and one internode.

The sub-aerial shoots differ from the rhizome by always having a very large central cavity, extending as before through the several internodes and being interrupted at the nodes. The arrangement of the steles is the same as in the underground stem. The cortex shows similar lacunæ, but it contains a number of bands of tissue with chloroplastids, which are situated opposite to the furrows. The sclerenchyma is developed in strands opposite to the ridges. The epidermis contains in its cell-walls copious deposits of silica.

The vascular bundles pursue a straight course down the internodes. At every node, each bundle bifurcates and the two halves diverge; each half unites with half of the next laterally placed bundle, the conjoint bundle passing then down the next internode in the same manner. At each point of junction of two half-bundles a strand from a leaf joins the united portions (*fig.* 913), so that the bundles are *common*.

The leaf is very rudimentary, having only a single small

vascular strand passing up the centre. It contains no assimilating tissue.

The vascular cylinder of the root is monostelic; the stele contains three wood and three bast bundles and is invested by a double-layered endodermis, from the innermost layer of which the lateral branches spring. There is no pericycle.

The sporangia are ovoid bodies, arranged with their long axes pointing towards the stem. Each is derived from several epidermal cells, the Equisetinæ being *eusporangiate.* The wall of the sporangium is one layer of cells deep, and these have peculiar thickenings similar to those of the anthers of the higher flowering plants.

The spores are all alike, the Equisetinæ being isosporous. A perinium, or epispore, is developed, resembling somewhat that of the spores of Marsilea. When the spores are mature, this coating splits up into four bands which coil round the spore, being attached to one point of its surface. These are known as *elaters*, and they aid in the dissemination of the spores by virtue of their hygroscopic qualities.

When the spore germinates it produces a gametophyte or prothallium very much like that of the Ferns, but somewhat more irregular in contour.

The prothallia are generally diœcious, producing antheridia or archegonia, but not both. Both antheridia and archegonia closely resemble in structure and development the corresponding organs in the Fern.

The embryo produced from the zygote has two cotyledons, contrasting with that of the Ferns, which has only one. The octants, with this exception, behave much as in the latter group.

The Equisetinæ were represented in Carboniferous times by a very prominent group of plants now known under the name of *Calamites.* Some of these were heterosporous. Though much like the existing forms, they showed a certain variety in the mode of arrangement of the sporophylls. They differed very greatly in anatomical structure on account of the bundles being *open* instead of *closed.* The band of cambium gave rise to considerable amounts of secondary wood and bast, so that the Calamites increased in thickness as do now the Dicotyledonous flowering plants.

Class VIII.—LYCOPODINÆ.

Like the Filicinæ, this class embraces both isosporous and heterosporous forms, and is divided accordingly. The plant is the sporophyte, and all the plants of the class are eusporangiate. Though of a somewhat higher type than the Ferns and Horsetails with regard to their processes of reproduction, their vegetative body is usually not so conspicuous, though in this respect there is a great deal of variety. The development of the embryo from the zygote, so far as it has been followed in the group, is much more like the process found in the flowering plants. The *foot*, so prominent in the embryo of the Ferns, is replaced by a cell or filament of cells known as a *suspensor*, and a special absorbing structure is developed from the epibasal portion of the embryo, which is often erroneously spoken of as a foot. It functions in the same way as a true foot, but is developed from an altogether different part of the embryo. We have, indeed, in the action of the foot in the Ferns and of this new organ in the Lycopodinæ an instance of the same physiological function being discharged by different morphological members.

Section 1.—Isosporous Lycopodinæ.

Included in this section are two Natural orders, Lycopodiaceæ and Psilotaceæ, each of which comprises two genera, Lycopodium and Phylloglossum, Psilotum and Tmesipteris.

Lycopodium is much the largest genus, comprising many species of very varying external appearance. Generally there is a very much-branched wiry stem, sometimes growing underground, sometimes creeping on the surface, sometimes erect. It is closely covered with variously arranged small, pointed leaves, which are very numerous. The stem sometimes branches dichotomously, sometimes monopodially.

Besides the foliage leaves the plant bears sporophylls, which are often very different in appearance from the former, and are collected into flowers at the end of the branches. The flowers are cones, consisting of spirally arranged leaves bearing the sporangia in their axils or on the upper surface of the leaf-stalk (*fig.* 916). In some species the collection of the sporophylls into cones is not so obvious, and then the sporophylls closely resemble the foliage leaves. The roots are all adventitious, and in many cases arise from superficial cells of the stem.

Phylloglossum has a tuberous stem, from the apex of which about six leaves spring. These are longer than in Lycopodium and form a sort of rosette, from the centre of which arises a peduncle bearing the single flower. This is a small simple cone, the upper leaves of which do not bear sporangia. The whole plant is only a few inches in height.

Psilotum is very much branched, and in appearance resembles a very small bush. It has a much-branched subterranean rhizome, from which arise numerous sub-aerial stems. There are no roots, the subterranean shoots discharging their functions. The foliage leaves are very much reduced, being very small and sparsely distributed. The sporophylls are bilobed and stalked.

Tmesipteris grows upon the trunks of tree ferns, the stems being pendulous and clustered. Each stem is slender and crowded with linear sessile foliage leaves, among which occur sporophylls much like the former, but stalked and bearing sporangia.

Fig. 914.

Fig. 914. *Lycopodium inundatum*, Marsh Club-moss. The stem is creeping, and bears numerous small sessile imbricate leaves.

The anatomy of the stem in this group presents some very characteristic features. The apical cell of the lower Cryptogams becomes replaced by a small-celled meristem resembling that of the apical growing point of the Phanerogams. In a few cases, but only exceptionally, an apical cell occurs. The stem is monostelic, and its vascular bundles are arranged radially as in most roots (*fig.* 915). There are generally a number of wood and of bast bundles, the protoxylem and protophloëm of which are placed alternately in a circle round the stele, abutting on the pseudo-pericycle. As the wood develops the separate bundles become united together, fusing into masses of irregular pattern, between which lie masses of bast similarly formed by fusion of the

primary bundles. In their downward course the fused masses of wood are found to separate again and rejoin in other ways, the anastomoses causing the transverse section of the stem to present different patterns at different levels. The endodermis is usually thick-walled, and surrounds a layer which occupies the place of a pericycle, but which is really cortical and not stelar in its origin. This layer gives rise to the adventitious roots.

The root is similar in structure to the stem, but it contains

Fig. 915.

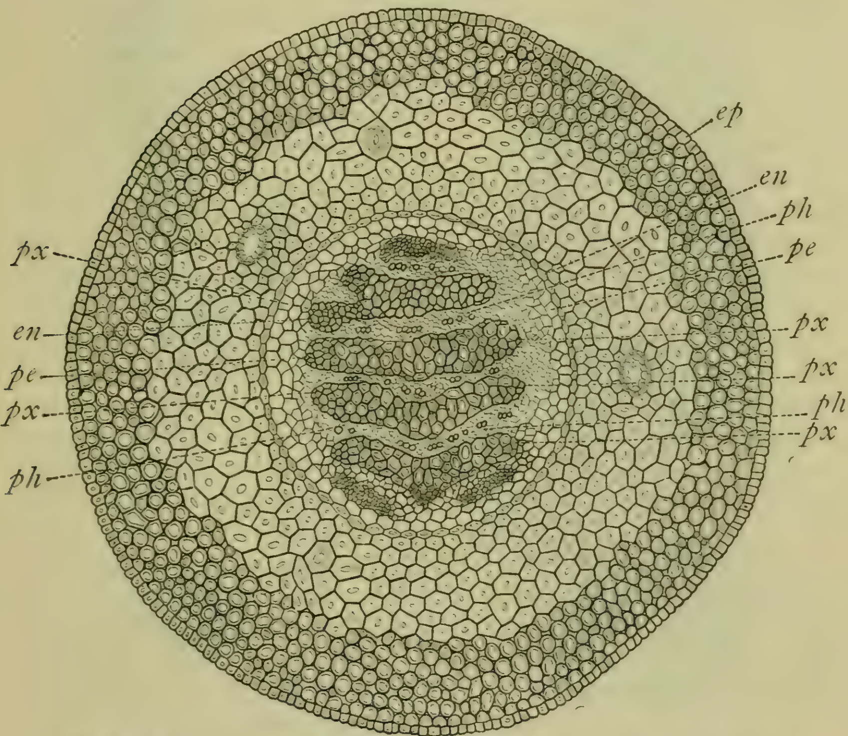


Fig. 915. Section of stem of *Lycopodium*. *ep.* Epidermis. *en.* Endodermis. *pe.* Pseudo-pericycle. *px.* Groups of protoxylem. *ph.* Phloëm. After Sachs.

fewer bundles of wood and bast. Its apical meristem is composed of small cells.

The stem or tuber of Phylloglossum contains little vascular tissue. Bundles from the leaves and roots anastomose where they enter it, and from the network a single strand passes up to the peduncle of the cone.

Both Psilotum and Tmesipteris agree with Lycopodium in being monostelic, with bundles arranged radially. The cortex of

the stem of Lycopodium can be divided into two areas, composed of thick-walled woody cells with small intercellular spaces. The cells of the inner area have very thick walls. The cortex is crossed by bundles passing out from the stele to the leaves.

The sporangia in Lycopodium and Phylloglossum are simple and stalked. They arise on the leaves near their insertion

Fig. 916.

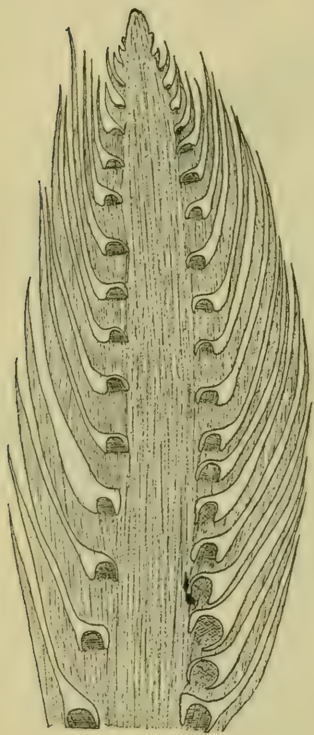


Fig. 917.

Fig. 916. Longitudinal section of cone of *Lycopodium*, showing the sporangia in the axils of the sporophylls.——*Fig.* 917. *Lycopodium annotinum.* *p.* Prothallium. *l.* The young plant. *w.* Its root. After Funkhauser.

(*fig.* 916). They arise from several cells instead of from a single one as in the ferns. They show no special peculiarity in their development. The spores are all microspores.

In Psilotum and Tmesipteris the sporangia are bilocular or trilocular, being *synangia*, as in the Marattias. They are stalked bodies, borne upon the upper surface of the bilobed sporophyll at the junction of its two lobes.

The gametophyte or prothallium (*fig.* 917, *p*) is only known in the genus Lycopodium, and shows considerable variety of form. In some species it is a small tuberous body, with a colourless base from which root hairs spring and an apex which is divided into several green lobes; in others it is altogether tuberous. In other species again it is larger and is a cylindrical branched body bearing gametophores. It bears both antheridia and archegonia, which resemble the corresponding organs in the eusporangiate Ferns. The antherozoids do not exhaust the protoplasm of the mother cells in which they are developed, but a small portion of it remains attached to them on their liberation as in the Ferns. They are biciliate.

The development of the sporophyte from the zygote is only known in *L. Phlegmaria*. The first division gives, as before, epibasal and hypobasal segments. The hypobasal cell does not as a rule divide, but elongates slightly to form the *suspensor*. The epibasal cell gives rise to the embryo, which consists of a primary stem, bearing a single cotyledon. The part of the axis below the cotyledon becomes the pseudo-foot already spoken of. It is really a *hypocotyl*. There is no primary or true root, but an adventitious one speedily arises from below the cotyledon.

In two other species (*L. cernuum* and *L. inundatum*) the later stages in the development have been followed, but the early ones are unknown. In them the appearance of the primary stem is preceded by the development of a tuberous body which bears the cotyledon and subsequently the stem at its apex. From its base adventitious roots arise exogenously.

Besides these modes of reproduction the vegetative method is not uncommon. Some species of Lycopodium multiply by gemmæ, others by tuberous outgrowths from the roots, others by the detachment of branches. Phylloglossum produces annually a single branch, which develops into the tuber of the succeeding year. Psilotum sometimes bears gemmæ on its rhizomes.

SECTION 2.—HETEROSPOROUS LYCOPODINÆ.

In this section we have two genera grouped together, about whose close affinity there is some doubt. These are *Selaginella* and *Isoëtes*. Of the relationship of the former to the isosporous Lycopodinæ there can be no doubt, but some authorities lean to the view that the affinities of Isoetes are rather to the Ferns than to the present group. This view is based upon its general habit, the large leaves and the small stem being much more like the

Ferns than the Lycopods; its embryogeny, the hypobasal cell not giving rise to a suspensor; the isolated position of its sporangia, and the form of its antherozoids. On the other hand, it shows relationship to the Lycopods in the occurrence of the sporangia on the upper surface of the leaf near the base; in the peculiar features of the gametophyte arising from the macrospore, which approaches the condition obtaining in the Gymnosperms even more closely than that of Selaginella; in the occurrence of a peculiar outgrowth of the leaf close to the sporangium, which is shared only by Selaginella; and in the structure of its apical meristem. The adventitious nature of the first root also supports this view of its position.

FIG. 918.

Fig. 918. *Selaginella helvetica.* s. Stem. o. Small leaves of upper surface. u. Larger leaves of lateral flanks.

The heterosporous Lycopodinæ have sometimes been called the *Ligulatæ*, from the occurrence of the particular outgrowth referred to, which is known as the *ligule*. Selaginella is the best known representative, and in many respects is the highest type represented in the group. Its form shows more variety than that of any other genus; the stem is slender, herbaceous, and sometimes erect, sometimes creeping; almost always showing a bilateral symmetry, which is very evident when it is much branched; the branches spread out in a flattened manner, and show an evident difference between the upper and under sides. The branching is apparently dichotomous and the stem a sympodium. Recent investigations tend to the view that the dichotomy is only apparent, and that it is really lateral.

The stem bears numerous small leaves of very simple structure. They are arranged in pairs, which are of unequal size, one leaf being much smaller than the other. The successive pairs decussate with each other, and in many cases, by some distortion in growth, the small leaves come to lie on the upper surface of the stem, while the larger ones are on the lateral flanks (*fig.* 918). Each leaf bears the peculiar ligule spoken of above.

The roots are adventitious as in other cases, even the primary root proceeding from the epibasal half of the zygote. This primary root soon perishes; the adventitious roots which succeed it spring from the lower surface of the stem, or from peculiar naked branches termed rhizophores, which grow down into the soil and develop roots from their apices.

The sporophylls are usually aggregated at the ends of certain of the branches; they form their flowers much as in Lycopodium, but there is not quite so sharp a distinction between the flowers and the foliage leaves as in the latter case. The sporangia, which are of two kinds, spring from the axils of the sporophylls, or in some cases from the surface of the stem just above the insertion of the latter.

The macrosporangia usually contain four macrospores; the number of microspores is generally large.

In the details of its anatomy Selaginella presents some very characteristic appearances. The apical meristem is sometimes small-celled and stratified, but in some species there is a definite apical cell. In others there is a group of two or three large cells which behave like apical cells. The stem as seen in section (*fig.* 919) is composed of parenchymatous or prosenchymatous cells, embedded in which are one to three steles, the polystelic condition being the most usual. There is no sclerenchyma, and but few intercellular spaces; sometimes, indeed, the latter are absent altogether. Each stele is enclosed in a large air-chamber, and this chamber is crossed by delicate rows of cells or trabeculæ, which attach the stele to the walls. The steles are gamodesmic, and consist of a variable number of bundles which have their protoxylem groups external, abutting on the pericycle. A frequent number of bundles in the stele is two of xylem and two of phloëm; in such case the structure much resembles the stele of the fern stem, but it differs in the protoxylem being on the outside instead of being internal. The structure is really of the same kind as in Lycopodium, the bundles being originally disposed radially. Not being so numerous as in the latter case, the subsequent fusions do not lead to so complicated a woody mass.

The leaves contain a single bundle, which in like manner is slung in an air-chamber. The base of the leaf is sometimes dilated into a kind of pulvinus, which is chiefly occupied by the air-cavity. The intercellular space system being so much reduced, the stomata of the leaf open into these air-chambers.

The tissue of the root is more compact, there are no air-

chambers, and usually a single central stele. The structure of the rhizophore resembles that of the root.

The sporangia are developed much as in Lycopodium; the macrosporangia differ from the microsporangia in the number of divisions that take place in the cells of the archesporium. In the latter case many mother-cells are produced, each giving rise to four tetrahedral microspores; in the former case not so many are formed, and only one of them as a rule divides to form spores. Hence the mature macrosporangium contains four macrospores.

Fig. 919.

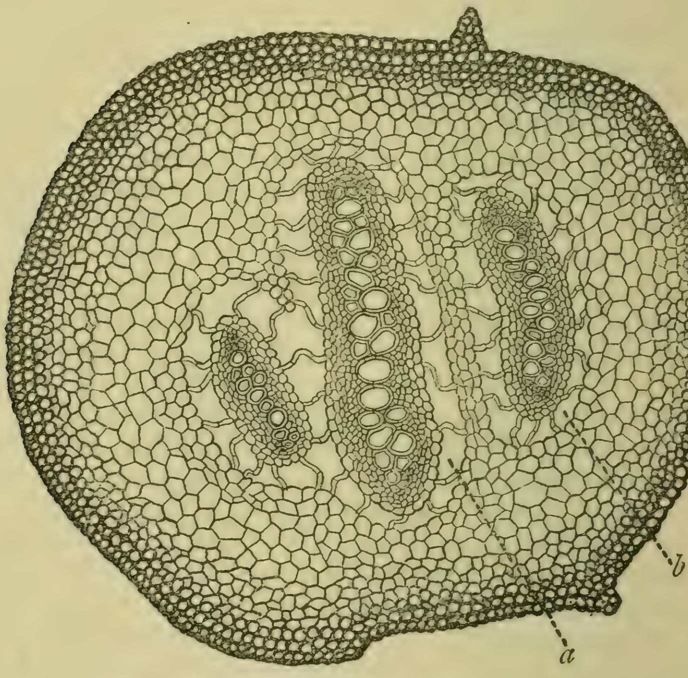


Fig. 919. Section of stem of *Selaginella* showing three steles. *a*, *b*, air chambers.

The male gametophyte arises from the microspore, and is very similar to that of Marsilea. The spore divides into two cells, a small vegetative one at the apex, and a large basal one which by repeated divisions produces a single antheridium, having a wall enclosing the mother-cells of the antherozoids. The microspore does not rupture until the antherozoids are developed.

The germination of the macrospore gives rise to a prothallium which is very largely endosporous. The spore contains a

small amount of protoplasm surrounding a large central vacuole. By free cell-formation a small primary prothallium is formed at the apex of the spore, which is soon separated from the remainder of the spore-cavity by thickening of the cell-walls of its lower layer, forming a *diaphragm* not unlike that of Salvinia. The protoplasm of the lower part of the spore increases till the cavity is filled with it. By free cell formation it develops a tissue much like that of the primary prothallium but with larger cells. This has been called the *endosperm*. The upper portion of the prothallium is after its formation exposed to light and air by the

FIG. 920.

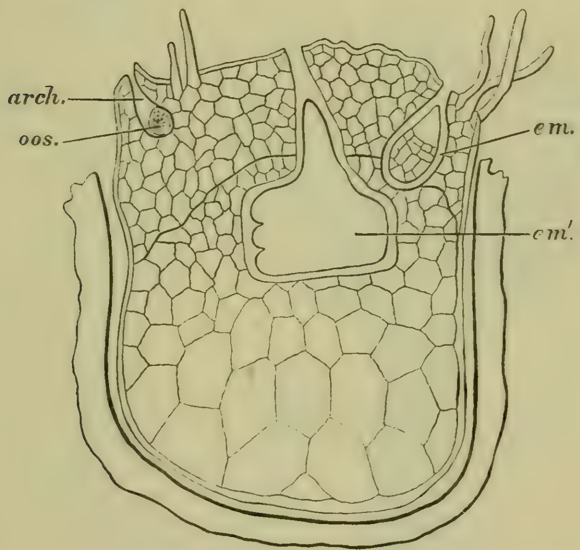


Fig. 920. Germination of macrospore of *Selaginella*. After Pfeffer. *arch.* Archegonium. *em, em'*. Young embryos.

rupture of the macrospore at its apex; it then becomes green from the development of chloroplastids. Generally it bears only one archegonium, always only a limited number. Frequently the number produced depends upon whether the first becomes fertilised. They have the same structure as those of the eusporangiate ferns.

The archegonia have the usual structure found in the group. Fertilisation of its oosphere is also normal.

When the zygote is formed and its germination begins, the process is similar to that of Lycopodium. The hypobasal segment becomes the suspensor, which by its elongation forces the

young embryo down into the tissue filling the cavity of the spore, the so-called endosperm. The epibasal cell forms four octants, and from these arise the growing points of the stem and of two cotyledons. As the growth of the embryo proceeds, a pseudo-foot is developed from the hypocotyledonary region, and the direction of growth of the axis becomes changed, so that the stem gradually curves upwards to emerge from the spore at the crack at its apical region, through which the prothallium is partially protruding. The foot remains embedded in the tissue of the endosperm and absorbs its contents. The first root is developed from cells in the interior of the hypocotyl between the foot and the suspensor.

Fig. 921.

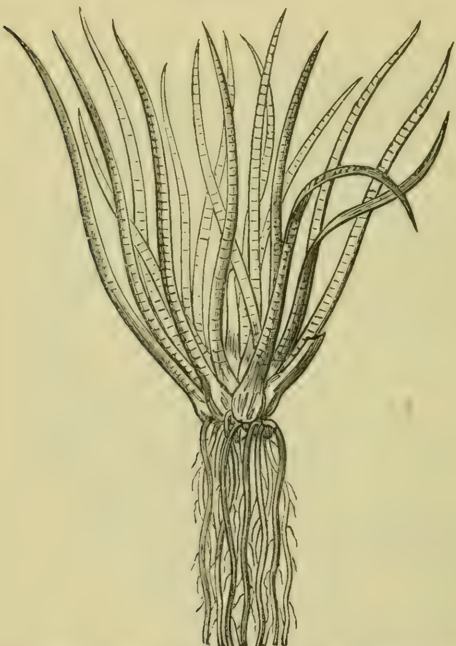


Fig. 921. *Isoëtes lacustris*, Lake Quill-wort. The stem is small and corm-like, and bears its leaves, which are linear-cylindrical, in tufts.

The other member of this section, *Isoëtes*, differs from Selaginella very markedly in its habit. It has a short tuberous stem somewhat lobed externally, from which spring numerous leaves in a cluster. The leaves are long and narrow, some of the cluster being fertile and some sterile. The fertile leaves bear large sporangia in a kind of pit upon the upper surface at their base. The microsporophylls are developed later than the macrosporophylls. Each leaf bears a ligule as in Selaginella. Numerous roots spring from the under side or base of the tuberous stem, and these branch dichotomously.

The stem is monostelic, and grows by a meristem, which consists of several large so-called apical cells. The stele is composed of a number of fused collateral bundles, which are common and run out into the leaves. Outside the bast of the bundles is a merismatic ring, which forms vascular tissue internally, and

externally adds to the cortex of the stem. Isoëtes thus increases in thickness, but somewhat irregularly, the distribution of the new cortical tissue being interrupted at places in the ring, so causing the furrows noticeable on its exterior.

The leaves have a single bundle, which is of a somewhat reduced type. It runs down the middle of the blade into the stem, and joins the ring of the stele. Four large air-spaces run down the whole length of the leaf in the parenchymatous tissue (*fig.* 922).

FIG. 922.

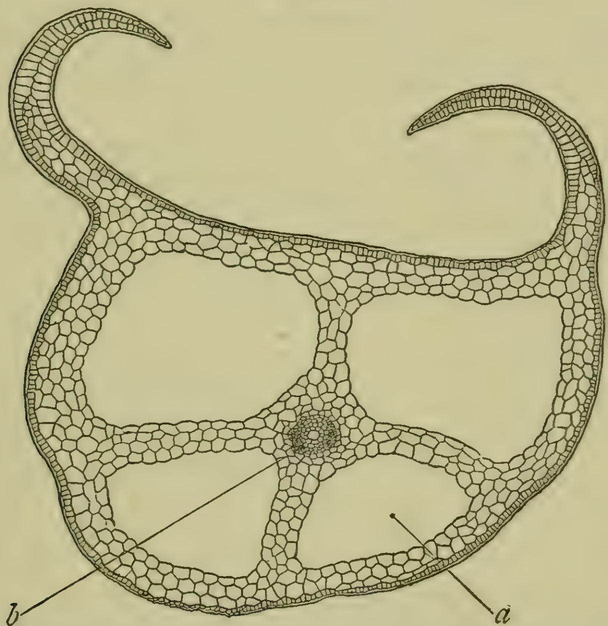


Fig. 922. Transverse section of leaf of *Iscëtes lacustris*. *a*. Air-chamber. *b*. Fibrovascular bundle.

The root differs from the stem in having a small-celled stratified apical meristem. Its stele contains only one or two bundles of xylem and phloëm.

The sporangia are much more bulky than in any other of the Lycopodinæ. They arise in a depression or pit on the upper surface of the leaf just above its base, a little below the insertion of the ligule. Isoëtes is eusporangiate, the sporangium arising from a group of cells. In the microsporangium the archesporial tissue, which becomes bulky, has its cells arranged in radial rows, springing from a sort of pad or cushion at its base. There takes

place in the archesporium then a process of sterilisation of certain of these cells, recalling the formation of the elaters in the Liverworts. The sterile cells extend as trabeculæ or strands across the interior of the sporangium, so that in transverse section it appears to be septate. In the microsporangium other cells also sterile, though derived from the archesporium, form a tapetum, which surrounds the mass of microspores. In the macrosporangium there is a similar formation of trabeculæ, but the arrangement of the rest of the archesporial tissue is different. There are fewer cells, which are consequently larger, and a tapetum is formed round each mother-cell.

The sterilisation of the tissue forming the trabeculæ, like that of the tapetum, is probably due to the need of distributing nourishment for the spores throughout the large sporogenous mass.

The gametophytes of Isoëtes closely resemble those of Selaginella. The prothallium derived from the macrospore is even more completely endosporous, the development being advanced to the stage of maturity of the archegonia before the spore splits. The prothallium consequently never becomes green. The antheridia and archegonia resemble in all points those of Selaginella.

The development of the young sporophyte from the zygote recalls that of the ferns. Both epibasal and hypobasal segments divide to form the octants; the hypobasal ones all combine to form the foot, but the first root is developed from the epibasal segments, which also give rise to the stem and the single cotyledon. The root is consequently adventitious, as in Selaginella.

Like the Equisetinæ, the Lycopodinæ were represented in Carboniferous times by very massive forms which showed great cambial activity in the development of their trunks and roots. Of these Lepidodendron is the best known example.

CHAPTER VI.

Group IV.

SPERMAPHYTA OR PHANEROGAMIA.[1]

This group of plants, so long considered as one standing apart from and above all others, or corresponding in classificatory value to the whole of the Cryptogams, is now held to be properly only upon an equal footing with the other groups already discussed. The gradual increase of complexity of structure of the sporophyte, associated with the progressive degradation of the gametophyte, reaches its maximum in this group, which appears as the fourth member of the series into which the Vegetable Kingdom is now divided.

The heterosporous character of the sporophyte, which we have seen to appear irregularly in the Pteridophyta, is here constant. The microspores are developed in much the same way and in about the same numbers as in the latter group; the macrospores show a considerable degradation, and the macrosporangia never become free from the parent plant until some time after their gametophytes are mature, not indeed until the young sporophyte or embryo produced by each of the latter has attained a considerable degree of development. The result is that a peculiar structure known as the *seed* makes its appearance for the first time in this group of plants. As its development shows some variability, it will be well, for the present, to defer its consideration. On account of its constant occurrence, the group is sometimes called the *Spermaphyta*.

The general morphology and anatomy of the group have formed the subject of the greater part of the first two sections of this manual, and need not, therefore, be treated of at length in the present chapter.

The chief remaining points calling for attention in connection with the Phanerogams are the structure of the sporophylls; the development of their sporangia, and spores; the gametophyte generation; and the embryogeny of the sporophyte.

The arrangement of the sporophylls has been discussed in connection with the morphology of the reproductive organs (Vol. I. Chapter II.), where their collection with other leaves into special branches, called *flowers*, has been fully treated of.

This development of a special branch system in connection with the occurrence of spores has been seen in the previous groups, especially in the Pteridophyta, not to be peculiar to the Phanerogams, but to be clearly indicated in the Equisetinæ and the Lycopodinæ. What is, however, exceptional in the lower forms becomes in the Phanerogams a constant and characteristic feature of their life.

It has been already pointed out that in the Phanerogams the sporangia, though usually borne upon leaves, are sometimes axial in their origin (*fig.* 923). This is seen in the case of both microsporangia and macrosporangia. When borne upon leaves, these are known as microsporophylls and macrosporophylls respectively. The microsporophylls are also called *stamens*, or staminal leaves; while the macrosporophylls are termed *carpels*, or in some cases carpellary leaves or scales.

Fig. 923.

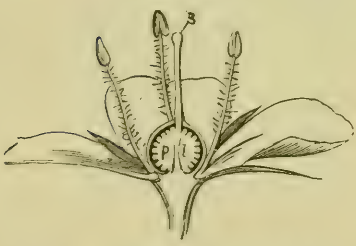


Fig. 923. Vertical section of flower of Pimpernel, showing axial macrosporangia.

The microsporangia, often called *pollen-sacs*, are situated at different places upon the stamen or staminal leaf. In the Gymnosperms they are upon the under side; in the Angiosperms upon both surfaces. The macrosporangia, or *ovules*, arise from a special parenchymatous cushion already described as the *placenta*, which in the Gymnosperms is usually on the ventral surface of the sporophyll or carpellary scale, but in the Angiosperms is almost always a development of the margin of the carpel. The carpel, or frequently the collection of carpels in a flower, forms by various cohesions at their bases in the latter case a closed chamber or *ovary* in which the macrosporangia are concealed.

Based on this latter point we have the classification of the Phanerogams into two large divisions, *Gymnospermæ*, in which the ovules are exposed, and *Angiospermæ*, in which they are enclosed in an ovary. Each of these large groups presents important peculiarities, the Gymnosperms approaching the

Pteridophyta much more nearly than the other forms, especially in the structure of the gametophyte and the differentiation of the sexual organs.

THE MICROSPOROPHYLLS, AND THEIR SPORANGIA.—The microsporophyll varies a good deal in its form; in the Gymnosperms it may be a flattened leaf with sporangia on its under surface; it may be a peltate scale, something like that of the flower of Equisetum, or it may be a short branched axis bearing a variable number of anther lobes. In the Angiosperms it is the structure already described as a *stamen*, consisting of a filament, carrying at its apex a swollen head or anther.

The Microsporangia are distributed in various ways upon the sporophyll; in most cases in groups which are to be considered as sori, corresponding to the sori in the Ferns and their allies. In the Gymnosperms the flattened staminal leaf of the Conifers has a sorus of two sporangia on its back; the sporophylls of the Cycads bear a number of groups of sporangia, each group representing a sorus. The anther of the Angiosperms contains a sorus of four sporangia, the pollen-sacs. The indusium or membrane covering the sorus in the Ferns is represented doubtfully in the Cupressineæ, where the sporangia when young are covered by an outgrowth of the under surface of the sporophyll.

Whether the sporangia arise upon a sporophyll or upon the axis, their mode of development is the same. They are eusporangiate, that is, they originate in a group of several cells. In the young anther, at four places, corresponding to the anther lobes, a row of hypodermal cells is seen to be somewhat different from the rest in their mode of dividing. In a transverse section of the anther they appear as four cells, as the row runs longitudinally. The hypodermal cell so seen in transverse section cuts off a cell from itself on its exterior face; this division is followed by another one parallel to the first, so that the original cell or archesporium is replaced by a row of three, of which the innermost has come to lie more deeply in the tissue. The outer two take no part in the development of the spores, which arise from the inner one. The one lying next to this is the first-formed part of a nutritive layer which is made to extend round the sporogenous cell by divisions taking place in the tissue next it. This layer is known as the *tapetum* and has only a transitory existence. The outermost of the three cells becomes similarly extended, and the walls of those cells which are towards the exterior become thickened spirally, con-

stituting the external wall of the pollen sac. Both these layers become composed of many cells, owing to radial or anticlinal divisions of those first formed. The innermost cell divides into a variable number of cells, which are the mother cells of the microspores or pollen grains. Each mother cell gives rise to four special mother cells; in the Monocotyledons by ordinary cell-division twice repeated, the plane of the second division being at right angles to that of the first: in the Dicotyledons the four special mother cells are arranged at the four angles of a tetrahedron, as described in the case of the ferns. Each special mother cell gives rise to a pollen grain, or microspore, by a process of rejuvenescence. The tapetum, and frequently the walls of the original mother cells, become disorganised, forming a sort of mucilaginous fluid in which the spores float. As they mature their walls are thickened from within and usually form two coats, the intine and the exine. The exine is often curiously marked with spines or ridges, due to the deposition of matter upon it from the disorganised tapetal cells. Eventually the spores lie free in the cavity of the sporangium.

FIG. 924.

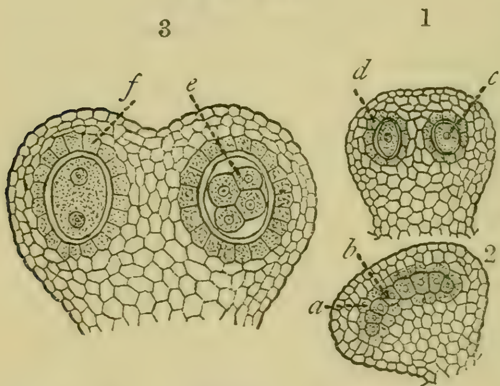


Fig. 924. Development of pollen in the stamen of Lavatera. 1, 2. Young stages. 1. Transverse, 2. Longitudinal, section of anther. *a*, *d*. Tapetum. *b*, *c*. Sporogenous cells. 3. Later stage. *f*. Tapetum. *e*. Four special mother cells of the pollen. After Dodel-Port.

Dehiscence is secured by the hygroscopic character of the wall of spirally thickened cells described above, which under different atmospheric conditions ruptures either by longitudinal or transverse slits, or occasionally by a pore at or near the apex.

The microspore so formed is a rounded, or oval, or rarely an elongated body, containing protoplasm and nucleus, and a quantity of reserve food material consisting of proteïds, starch, oil, &c. It has usually two coats, of which the outer is hard and thickened, the inner thin and delicate. In some of the Gymnosperms the outer coat is expanded at two places at the base of the spore to form two bladder-like bodies which are filled with air.

The two coats are usually distinct from each other, but in some pollen grains they are adherent, except at special spots, at which the exine will rupture when the spore germinates. In some cases there is no exine, particularly in some aquatic plants.

The microspores do not always become free from each other; in the Mimosæ they are bound together by the special-mother-cell walls into groups of four or more; in the Orchids and Asclepias the whole mass is usually coherent, forming the *pollinium*.

THE MACROSPOROPHYLLS AND THE MACROSPORANGIA.—The appearance of the macrosporophylls has already been described. In the Angiosperms they are the carpels, and may be either free or coherent together. In the Coniferæ of the Gymnosperms they are flattened, scale-like leaves, each of which bears two sporangia on its upper face. In some of the Cycads they are small pinnate leaves, the lower pinnæ only bearing the sporangia. In others they are peltate scales with the latter on their under side, much resembling the microsporophylls.

FIG. 925.

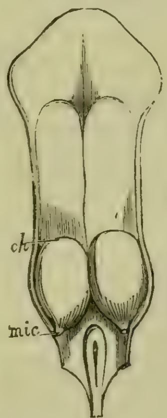


FIG. 926.

Fig. 925. A mature carpel or scale of the Scotch Fir (*Pinus sylvestris*), with two winged naked seeds at its base. *mic.* Micropyle. *ch.* Chalaza.——*Fig.* 926. A scale of the Larch, bearing one naked winged seed; the other seed has been removed.

The development of the macrosporangium or ovule takes place by the division of certain hypodermal cells of the placenta, whether the latter be upon a sporophyll or upon the axis. These cells divide repeatedly periclinally till the young sporangium appears as a little protrusion of tissue, whose cells are arranged in radial rows (*fig.* 927). In the most usual case the terminal cell of the central row becomes the archesporium. The growth of the mass of the sporangium, known as the nucellus, has already been described (Vol. I. p. 207) and its various shapes mentioned. From its base arise the integuments, usually two in number, which accompany it in its growth and finally surround it, except at the apex, where the micropyle is left.

While this development is proceeding changes take place in the interior. The original archesporium, which is a single cell,

cuts off one or sometimes two cells at its apex, the innermost of which represents the tapetum. These tapetal cells sometimes divide repeatedly, especially in the Gymnosperms, so that the innermost cell often comes to lie deep in the tissue of the nucellus. This is often, in the same group, secured by additional multiplication of cells derived from the epidermis

FIG. 927.

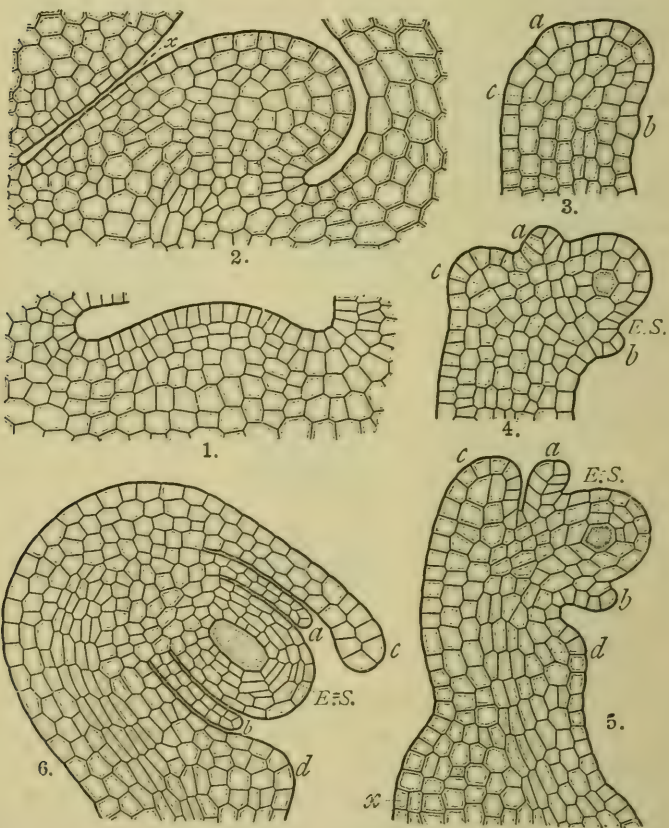


Fig. 927. Early development of the anatropous ovule of Viola. 1–6. Successive stages. *a*, *b*. Inner integument. *c*, *d*. Outer integument. E. S. Embryo sac. After Kny.

of the nucellus over the apex of the archesporium. The innermost cell produced by the archesporial divisions now enlarges to a considerable extent. It represents the mother cell of the spores of the microsporangium. Instead of dividing to form special mother cells as in the latter, it becomes itself

the single spore. It was formerly described as the *embryo sac*, as the embryo ultimately makes its appearance in it. During its growth, which is very considerable, it absorbs the cells around it, often to such an extent that it leaves nothing of the original nucellar tissue. It may even encroach upon the integuments. It then forms a large cell, clothed only by the integuments of the sporangium. If the absorption of the nucellus is not complete, the remainder of its cells form the tissue already alluded to as the perisperm.

The nucellus of the ovule is seen thus from its development to be the macrosporangium of the Phanerogam, and to correspond to the macrosporangium of Selaginella. It differs from the latter in that the mother cell of the spore becomes itself the spore, whereas in Selaginella the corresponding cell divides twice, forming four macrospores. It differs further in not secreting a thickened coat, its wall always remaining thin and delicate, except in the Cycadeæ, where it is double.

The integuments of the ovule correspond to the indusium, which in Salvinia and Azolla has been shown to be two-layered and to grow over and enclose the sporangia. The integuments do not completely close over the ovule, while in the former case they shut the sporangia in entirely.

The structure in the Phanerogams recalls the condition in Azolla more than in Salvinia. In Azolla the sorus of macrosporangia consists only of one, and this one is invested by the indusium just as the ovule is surrounded by its integuments. The macrosporangia in the Phanerogams are thus solitary as in Azolla, or in other words the sorus is monosporangiate.

Though this is the usual course of development in the Phanerogams, there are many variations of the process known. More than one row of cells in the nucellus may give rise to archesporia, and consequently more than one embryo sac or macrospore may be produced. Eventually only the central one becomes mature, the others perishing early. In some cases, instead of a single spore mother cell occurring, this divides into a number of sporogenous cells, of which again several may begin to develop into macrospores, though ultimately only one of them matures. In a few plants the original archesporium does not cut off any tapetal cells.

The features of the gametophyte generation and the embryogeny of the sporophyte differ considerably in the Gymnosperms and the Angiosperms, and will be best described in connection with those respective groups.

DIVISION A.—GYMNOSPERMÆ.

Class IX.—GYMNOSPERMÆ.

The plants included in this class are distinguished by their macrosporophylls never forming an ovary, the carpels being usually flattened and bearing the macrosporangia on their upper surfaces. In habit they are shrubs or trees, generally of considerable size. In our climate they are chiefly represented by the Coniferous trees, Firs, Larches, &c., which have a monopodially branched stem, bearing usually long branches, on which dwarf shoots are thickly placed, the latter consisting of small fascicles of two to several elongated green leaves springing from a short axis and surrounded at their base by minute withered or brown scales. The long branches bear no foliage leaves except what arise from their dwarf shoots.

The stem in other members of the group is a short thick trunk, bearing large pinnate leaves; in *Welwitschia* it is very short and bears only two leaves, which are very long.

A few forms have a bushy habit, with wiry stems which bear no foliage leaves, but only a number of scales.

The sporangia are of two kinds, as already stated. The microsporophylls are usually collected into cones, and bear the sporangia on their lower surfaces. The macrosporangia are axial in *Taxus* and in the *Gnetaceæ*; in the other cases they are borne on sporophylls. These, like the microsporophylls, are generally arranged in cones, but the sporangia are on the upper surface at the base of the sporophyll, sometimes upon a large placental scale. In *Cycas* the sporophyll is a pinnate leaf, the lower pinnæ of which are replaced by macrosporangia. A cluster of these sporophylls is developed at the apex of the stem among the foliage leaves.

The development of the sporangia and of the spores has already been described.

A few features of the histology are remarkable. The stem is of the same type as the Dicotyledons, but is peculiar in that the wood formed by the cambium, except in the Gnetaceæ, always consists of fusiform tracheïds with bordered pits upon their radial walls. The sieve tubes, like those of the Pteridophyta, have no companion cells. There is a great development of

secreting ducts in most cases, the secretion being either resin or mucilage.

THE GAMETOPHYTE.—As there are two kinds of spore, there are two forms of gametophyte, the male organs occurring on the one developed from the microspore, the female on that proceeding from the macrospore.

The pollen grain generally begins to germinate before it is set free from the microsporangium. It divides into two, one of which is much larger than the other. The smaller is known as the *antheridial* cell, the larger as the *vegetative* one. In some species more than one small cell is produced, the whole series of them being then looked upon as a rudimentary prothallium, and the last formed being the antheridial cell. After escaping from the sporangium the vegetative cell grows out into a long filamentous body, known as the pollen tube; it is composed only of the intine of the spore, the exine rupturing to give it exit.

The antheridial cell divides into two, a stalk cell and a generative cell. The generative cell and the nucleus of the vegetative cell both make their way down the pollen tube; the vegetative nucleus breaks up and disappears; the generative cell divides into two, which represent the mother cells of antherozoids of the Pteridophyta. The antherozoid is, however, not differentiated. In some forms there is a still further division of the generative cells at the apex of the pollen tube. The ultimate cells, whether the divisions be one or many, are naked cells and constitute the male gametes. They are eventually extruded from the pollen tube.

The prothallium which is produced from the macrospore is sometimes called the *endosperm*. It is never exposed as in the Pteridophyta. The nucleus of the macrospore divides repeatedly till a large number of nuclei are present; these are arranged in a layer in the protoplasm lining the spore; then between them cell-walls are formed, and a peripheral cellular layer is thus constituted. The cells of this layer by ordinary cell-division produce a tissue which fills the spore. This is the prothallium. Archegonia are developed at its apical end, having almost the same structure as in the Pteridophyta. They arise from superficial cells, and have a neck and a venter, in which lie the neck-canal-cells, ventral-canal-cells, and oosphere respectively.

Fertilisation is brought about by the microspore germinating upon the apex of the macrosporangium. The pollen tube penetrates the latter by the micropyle and bores its way into the tissue of the nucellus during its development, as described above.

The apex of the tube comes to the summit of the macrospore, where the necks of the archegonia are situated. It pierces the coat of the spore and either enters the neck of a single archegonium or spreads over several. A male gamete is extruded from the tip into the oosphere or oospheres as the case may be, and the nuclei of the two gametes fuse to form the nucleus of the new zygote.

This is the general arrangement throughout the group; but variations are found in some forms, particularly in the Gnetaceæ.

Fig. 928.

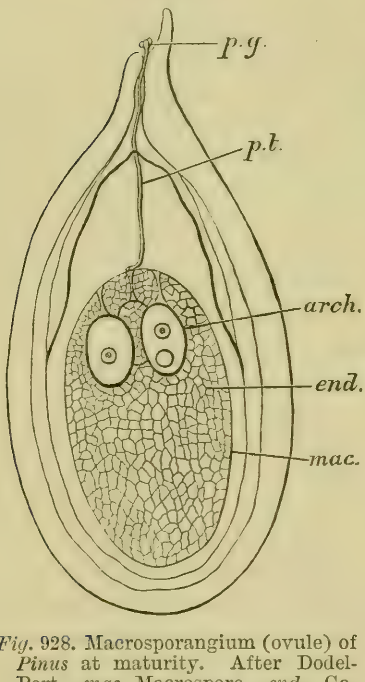


Fig. 928. Macrosporangium (ovule) of *Pinus* at maturity. After Dodel-Port. *mac.* Macrospore. *end.* Gametophyte or prothallium. *arch.* Archegonia. *p.g.* Pollen-grain or microspore, which has been transported to the micropyle of the ovule and has put out its prothallium, the pollen-tube, *p.t.*

The fate of the zygote differs a good deal in the different Natural Orders of the group. The Coniferæ are the most regular, and may be first discussed. The embryo is derived from only part of the zygote; its nucleus goes down to the base of the cell and divides into two, and each again into two; the four nuclei become four cells by protoplasm aggregating round them and cell-walls being formed between them. Each cell of the four divides twice transversely, so that instead of four cells there are four tiers, each tier consisting of three cells. Each of the middle cells grows out into a suspensor, the top cells of each tier attach the suspensor to the rest of the zygote, while the terminal cells give rise to four embryos.

This mode of development is that characteristic of the Abietineæ; in the Cupressineæ a single tier of three cells is first formed; in *Thuja* only the two upper cells undergo longtitudinal division, so that a single embyro is found, furnished with four suspensor cells; in *Juniperus* all three divide as in the Abietineæ. *Picea excelsa* of the Abietineæ resembles Thuja in only forming one embryo instead of four. In the Cupressineæ the elongation

to form the suspensor takes place in the top cell as well as the middle one.

In the Cycadeæ the embryo is formed by a process of free-cell formation leading to the construction of a mass of cells, the lower part of which grows out into the tissue of the prothallium forming a suspensor, at the end of which an embryo is developed. *Ephedra* of the Gnetaceæ behaves similarly, but each embryonic cell grows out separately in the same way, and so a number of embryos are formed; in *Ginkgo* the mass of cells formed in the zygote constitutes the embryo, and there is no suspensor. Other modifications occur in *Welwitschia* and *Gnetum*.

In most cases the zygote gives rise to a number of embryos; in the ripe seed, however, only one is usually present, the others perishing in the course of development.

Fig. 929.

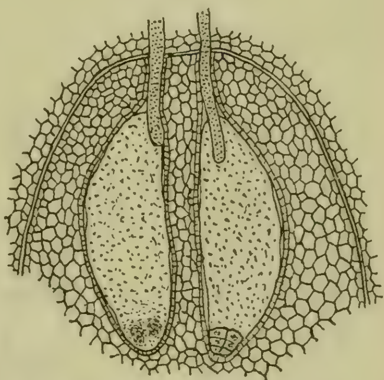


Fig. 929. Beginning of development of embryo in *Pinus*. The right-hand ovum is a little the more advanced.

The seed is always albuminous; a good deal of the prothallium persists, forming an endosperm, and a certain amount of the original nucellus is also present, forming perisperm. The embryo is found embedded in the endosperm: it consists of an axis, with plumule and radicle, and bears a variable number of cotyledons, sometimes only one, sometimes as many as fifteen. The growing point of the root is peculiar, being differentiated in the body of the embryo, some distance from its lower end. The integument of the macrosporangium becomes hard and woody and forms the testa of the seed.

The macrospore remains in the sporangium or ovule all the time these changes are proceeding, and the sporangium does not become detached from the sporophyte from which it originated. The resulting structure is the seed whose composition has just been described. In this body we have consequently three generations represented. From the original sporophyte are derived the testa, the perisperm or nucellus of the macrosporangium, and the embryo sac or macrospore. From the gametophyte we have the endosperm or prothallium. From the zygote, the commencement of the new sporophytic genera-

tion, we have the embryo, which is the young sporophyte itself.

The Gymnosperms are subdivided as under:—

Order 1. CONIFERÆ or PINACEÆ, the Coniferous or Pine Order.—Character.—Resinous *trees* or evergreen *shrubs*, with branched continuous stems. *Leaves* linear, acicular or lanceo-rate, parallel-veined, fascicled or imbricate alternate. *Flowers* naked, monœcious or diœcious. *Male flowers* arranged in deciduous amenta. *Stamens* 1 or several, in the latter case monadelphous; *anthers* 1- or more-celled, opening longitudinally. *Female flowers* in cones, consisting of flattened imbricate carpels or scales arising from the axil of membranous bracts; *ovules* naked, 2 or more, on the upper surface of each carpel. *Fruit* a

FIG. 930.

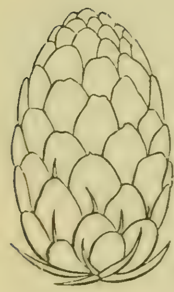


FIG. 931.

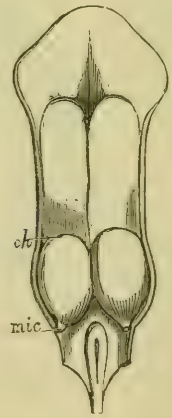


FIG. 932.

Fig. 930. A ripe cone of the Larch (*Pinus* (*Abies*) *Larix*).——*Fig.* 931. A mature carpel or scale of the Scotch Fir (*Pinus sylvestris*), with two winged naked seeds at its base. *mic.* Micropyle. *ch.* Chalaza.——*Fig.* 932. A scale of the Larch bearing one naked winged seed; the other seed has been removed.

woody cone or a galbulus. *Seeds* naked with a hard crustaceous integument, albuminous; *cotyledons* 2 or many.

Division of the Order and Illustrative Genera.—This order has been subdivided as follows:—

Sub-order 1. *Abieteæ.*—Ovules inverted, with the micropyle next the base of the carpel. Pollen curved.
Illustrative Genera:—Pinus, *Linn.*; Araucaria, *Juss.*

Sub-order 2. *Cupresseæ.*—Ovules erect, with micropyle superior. Pollen spheroidal. *Illustrative Genera*:—Juniperus, *Linn.*; Cupressus, *Tourn.*

The order Taxaceæ is now frequently included in the Coniferæ, forming the tribe or sub-order Taxeæ or Taxineæ.

Distribution and Numbers.—The plants of this order occur

in all parts of the world; but they abound most in temperate climates. There are about 250 species.

Properties and Uses.—They possess very important properties. Many supply valuable timber, and most of the species contain an oleo-resinous juice or turpentine, which is composed of a volatile oil and resin.

Order 2. TAXACEÆ, the Yew Order.—Character.—*Trees* or *shrubs*, with continuous branches. *Leaves* usually narrow, rigid, and veinless; sometimes broad, with forked veins. *Flowers* unisexual, naked, bracteate. *Male flowers* several together, each with one or several stamens, which, in the latter case, are united or distinct; *anthers* bursting longitudinally. *Female flowers* solitary, and consisting of a single erect naked ovule, which is either terminal or placed in the axil of a bract. *Seed* small, usually more or less surrounded by a cup-shaped fleshy mass or aril, albuminous; *embryo* straight. *This order is now frequently included in the Coniferæ, forming the tribe or sub-order Taxeæ or Taxineæ.*

FIG. 933.

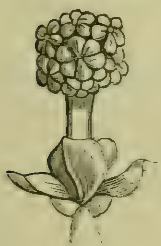


FIG. 934.

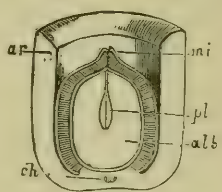


Fig. 933. Male flower of the Common Yew (*Taxus baccata*), with numerous monadelphous stamens.——*Fig.* 934. Vertical section of the seed of the same. *ar.* The succulent cup-shaped mass which surrounds the seed. *pl.* Embryo. *alb.* Albumen. *ch.* Chalaza. *mi.* Micropyle.

Distribution and Numbers.—Natives of the mountains of tropical countries, and of temperate regions. *Illustrative Genera*:—Taxus, *Linn.*; Salisburia, *Smith.* There are about 50 species.

Properties and Uses.—In their general properties they resemble the Coniferæ.

Order 3. GNETACEÆ, the Jointed Fir Order.—Character. Small *trees* or *shrubs*, with usually jointed stems and branches. *Leaves* opposite, entire, net- or parallel-veined, or sometimes small and scale-like. *Flowers* unisexual or rarely hermaphrodite, in catkins or heads. *Male flowers* with a 1-leaved *calyx*; *anthers* 2—3-celled, with porous dehiscence. *Female flowers* naked or surrounded by 2 more or less combined scales; *ovules*

1—2, naked, pointed by a style-like process. *Seed* succulent; *embryo* dicotyledonous, in the axis of fleshy albumen.

Distribution and Numbers.—These plants occur in both tropical and temperate regions. There are 3 genera—Ephedra, *Linn.*; Welwitschia, *Reichb.*; and Gnetum, *Linn.*; and about 30 species.

Properties and Uses.—Unimportant. The seeds and leaves of several species are eaten. Some *Ephedras* are astringent.

Order 4. CYCADACEÆ, the Cycas Order.—Character.—Small Palm-like unbranched or occasionally dichotomous *trees* or *shrubs*, with their surface marked by the scars of fallen leaves. *Leaves* clustered at the summit, pinnate, parallel-veined, hard and woody; leaflets sometimes circinate in vernation. *Flowers* quite naked, unisexual, diœcious. *Male flowers* in cones, consisting of scales, from the under surface of which 1-celled pollen sacs arise. *Female flowers* consisting of naked ovules placed on the margins of altered leaves, or of ovules arising from the base of flat scales or from the under surface of peltate ones. *Seeds* hard or succulent, with 1 or several embryos contained in fleshy or mealy albumen.

Distribution and Numbers.—Natives principally of the temperate and tropical parts of America and Asia; and occasionally of the Cape of Good Hope, Madagascar, and Australia. *Illustrative Genera*:—Cycas, *Linn.*; Zamia, *Lindl.* There are about 50 species,

Properties and Uses.—The stems and seeds of the plants of this order yield mucilage and starch.

Artificial Analysis of the Orders in the GYMNOSPERMÆ.

1. *Stem jointed, branched* . . . . . . *Gnetaceæ.*
2. *Stem not jointed.*
    - Branched. Leaves simple.
        - Carpels collected in cones . . . . *Coniferæ.*
        - Seed solitary, usually surrounded by a succulent coat . . . . . . *Taxaceæ.*
    - Not branched or dichotomous. Leaves pinnate *Cycadaceæ.*

DIVISION B.—ANGIOSPERMÆ.

In this division the evolution of the flower reaches its highest point; the micro- and macrosporophylls are usually found in the same flower; the former are, as a rule, much modified in shape, and their foliar character is at first sight difficult to grasp; they form the structures described already as *stamens*, each consisting normally of a *filament* and an *anther*, the latter bearing the microsporangia or pollen-sacs. The macrosporophylls are carpels, and are either distinct or coherent together. In either case the ovules or macrosporangia are contained in a closed cavity, or ovary, formed by the cohesion in various ways of the carpellary walls. Each ovary is crowned by a *stigma*, which is often separated from the ovary by a filiform structure called the *style*.

The pollen grain, instead of entering the micropyle of the ovule and germinating there, falls upon the stigma and there develops its gametophyte, which penetrates the tissue of the style in the form of the pollen tube and makes its way into the cavity of the ovary, ultimately reaching the ovules. It generally enters the latter at the micropyle and so makes its way to the gametophyte of the macrospore or embryo sac, which is situated just below the micropyle. In a few cases it finds its way to the female cell by burrowing through the tissue of the ovule and of the gametophyte from the chalazal end. This, however, is exceptional, and only occurs in a few families.

The gametophyte produced by the macrospore is always completely internal or endosporous, and is very much reduced. It bears the female cell or oosphere at its micropylar end, and this cell is not enclosed in an archegonium (*fig.* 935).

Histologically the group shows an advance upon the structure of the Gymnosperms in the greater variety of the elements composing the wood and bast. The wood contains true vessels, which show the varieties of thickening already described. The sieve tubes always have companion cells. The development of the spores takes place in the way already described. In a few cases modifications of the process are found. In *Asclepias* and *Zostera* the mother cells of the pollen do not form four special mother cells, but each becomes a microspore.

The Gametophyte.—As in the Gymnosperms we have two forms of the gametophyte, the one coming from the microspore, the other from the macrospore.

The prothallium developed from the microspore is more reduced than in the last group. When the spore is shed, or sometimes while it is still in the sporangium, the nucleus divides into two, but this division is not followed by the formation of a cell-wall. The protoplasm of the spore aggregates round the two nuclei, forming two *primordial* or naked cells, one of which is the *generative*, the other the *vegetative* cell. The exine ruptures, often at particular spots, but sometimes irregularly, and the intine grows out into a long tube, the *pollen tube.* In some cases, as in the Malvaceæ, several tubes arise from different points on the spore.

The pollen tube is derived from the larger of the two cells, the vegetative one, as in the Gymnosperms. The generative cell passes into the tube, as does the vegetative nucleus. As they proceed down the tube, the generative cell divides into two, forming two gametes, which correspond to the antherozoids of lower forms, but they are never differentiated as in the latter case. The vegetative nucleus becomes disorganised and disappears.

By the time that the pollen tube has reached the gametophyte of the macrospore the process is complete, and the tube remains with its two gametes at or near its apex. The protoplasm of the tube is richly vacuolated, and the granules it contains show extensive movements of circulation.

The macrospore produces its gametophyte in its interior as in the Gymnosperms, but the prothallar tissue is very much smaller (*fig.* 935). The nucleus of the macrospore divides into two, and each travels to one end of the spore. Each then divides into two, and each of the daughter nuclei repeats the process, so that at that stage the spore contains two groups each of four nuclei, one at the micropylar and the other at the chalazal end. One nucleus from each of these groups then travels to the centre of the spore, and the two fuse together, constituting what is known as the *definitive nucleus* of the embryo sac. A certain amount of protoplasm aggregates round each of the three nuclei at the two ends, forming two groups of three cells each. Those at the chalazal end secrete cell-walls and form the *antipodal cells*, which take no further part in the development; those at the micropylar end remain naked and constitute the *egg apparatus.* One of these, whose nucleus is the sister nucleus of the one

which descended to help form the definitive nucleus, is the female gamete, or *oosphere*, while the other two are known as the *synergidæ*. In some few cases the definitive nucleus is constituted by only the one from the chalazal end; there are then two oospheres, of which only one becomes fertilised. In rare cases the synergidæ are fertile gametes, though this very seldom happens.

At this stage the development of the prothallium remains suspended, and nothing further takes place unless the oosphere becomes fertilised. The egg apparatus lies almost always immediately below the micropyle, and is thus not covered by a mass of tissue as in the Gymnosperms. The pollen tube reaches the micropyle as already described; its apex becomes more or less mucilaginous, as does the wall of the embryo sac, and one of the male gametes makes its way through to the oosphere, with which it fuses, nucleus with nucleus and protoplasm with protoplasm. The fertilised oosphere, now become a zygote, surrounds itself with a cell-wall, and the synergidæ become disorganised and disappear.

Fig. 935.

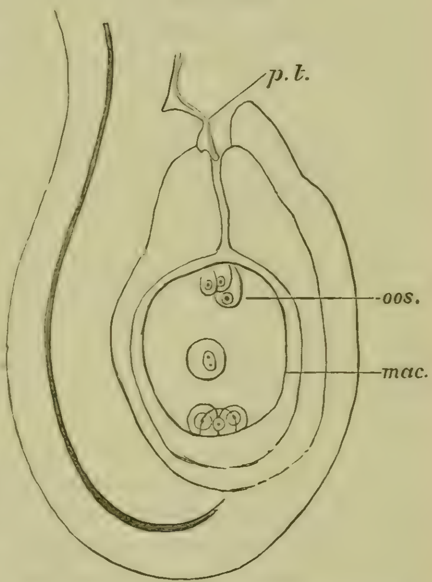


Fig. 935. Macrosporangium (ovule) of an Angiosperm. *mac.* Macrospore. *oos.* Oosphere. *p.t.* Pollen-tube.

The further fate of the zygote differs in the two classes into which the Angiosperms are divided and will be discussed later. The embryo sac becomes filled with a tissue known as the *endosperm*, which has, however, a different morphological value from the tissue in the macrospore of the Gymnosperms, though it bears the same name.

This so-called endosperm is derived from the definitive nucleus of the embryo sac. This body divides repeatedly, forming a number of nuclei which become disposed in a layer all over the surface of the wall of the embryo sac. Round each of these an aggregation of protoplasm takes place, so that the sac

has a lining of naked or primordial cells. These become separated from each other and from the cavity of the spore by cell-walls, and the cells so formed divide repeatedly till, in most cases, the part of the embryo sac not occupied by the body resulting from the divisions of the zygote becomes filled with a mass of tissue which is the endosperm. In a few cases the endosperm does not completely fill the spore, but leaves a hollow cavity in the centre.

The young embryo, derived from the zygote in a manner still to be explained, together with the endosperm and the remains of the microsporangium and its coats, forms the body frequently alluded to above as the *seed*. The coats or integuments of the macrosporangium generally become hard and form the *testa* of the seed.

In some cases the endosperm is not formed by free-cell-formation as described above, but by ordinary cell-division, walls being developed after each nuclear fission.

In some plants this condition of things persists, and the embryo in the ripe seed is embedded in the endosperm. In others the embryo grows vigorously, and in its enlargement absorbs the contents of the endosperm cells. The seed then shows only the embryo surrounded by the testa. Generally the seed leaves or cotyledons are the parts which form the bulk of the embryo in such cases.

When fertilisation has been effected, and the zygote is formed, it at once commences its further development. There is no pause between the maturity of the gametophyte and the origination of the new sporophyte. A resting period occurs later, when the young plant has attained a certain size and when the endosperm has been formed and perhaps absorbed. The zygote divides into two by a transverse wall, and the two cells so formed, which correspond to the epibasal and hypobasal cells of the Pteridophyta, give rise, as in the latter case, to different structures. The hypobasal segment, which is the one nearest to the micropylar end of the embryo sac, develops into a chain of cells known as the *suspensor*, a structure noticed as occurring in a similar manner in the embryogeny of the Lycopodinæ. The suspensor does not become free from the protoplasm of the embryo sac, in which the oosphere was originally placed, and hence attaches the embryo to the embryo sac in a way indicated by the name *suspensor*. The suspensor, as a rule, soon perishes, so that only traces of it can be seen in the seed; sometimes, however, it grows to great length. In the Orchidaceæ cases occur where it assumes such a

size as to make its way out of the embryo sac through the micropyle and to ramify in the interior of the ovary and the tissue of the placenta. In some Dicotyledons a somewhat similar behaviour is found. In such cases it recalls physiologically as well as morphologically the *foot* of the Ferns and their allies, absorbing nutriment for the support of the embryo.

The suspensor contributes a cell to the formation of the embryo in a manner to be described below.

The epibasal cell, often termed the *embryo cell*, divides very differently. In it three walls are formed successively at right angles to each other, dividing it into eight octants. The octants in this group, it will be noticed, all proceed from the epibasal cell only and not from the whole zygote as in the Ferns, &c. The recent separation of the hypobasal cell causes the epibasal one not to be a sphere as is the zygote, so that the octants next the suspensor are flattened somewhat and abut upon the latter in a somewhat truncated fashion. The subsequent divisions differ somewhat in the Dicotyledons and the Monocotyledons. In the former group the anterior octants give rise to the upper portion of the axis, but the posterior ones only form the hypocotyl, the primary root being formed from the last cell of the suspensor, the so-called *hypophysis*. In the latter group this cell gives rise to the growing point of the laterally produced stem, and the root originates in the segment of the hypophysis next to the rest of the suspensor.

When the octants have been formed, the next step in the development is the formation of the dermatogen by walls parallel to the surface of the embryo. At first the dermatogen is incomplete, the periclinal walls only being formed in the octants. Soon it is continued across the hypophysis, which has by this time grown up in a slightly bulging fashion at the base of the embryo (*figs.* 936 and 937). Of the cells so formed from the hypophysis the internal one gives rise to the periblem of the root, while the latter forms its dermatogen, which soon becomes many-layered and constitutes the root cap. The further growth of the embryo soon gives rise to the three systems of tissue already described, the *dermatogen*, *periblem* and *plerome*.

In the Monocotyledons the terminal cotyledon is developed from the octants, the hypophysis dividing to form a row of cells, of which the anterior ones give rise to the stem while the posterior one forms the root, as the whole hypophysis does in Dicotyledons. The order of division of cells is very similar,

and the embryo becomes differentiated histologically in the same way. The young stem is derived from the upper cell of the two resulting from the first division of the hypophysis, and as it assumes its form it turns out laterally from below the cotyledon.

This division of the Phanerogamia includes the two classes of Monocotyledons and Dicotyledons, which are distinguished from each other by the following points:—

FIG. 936.

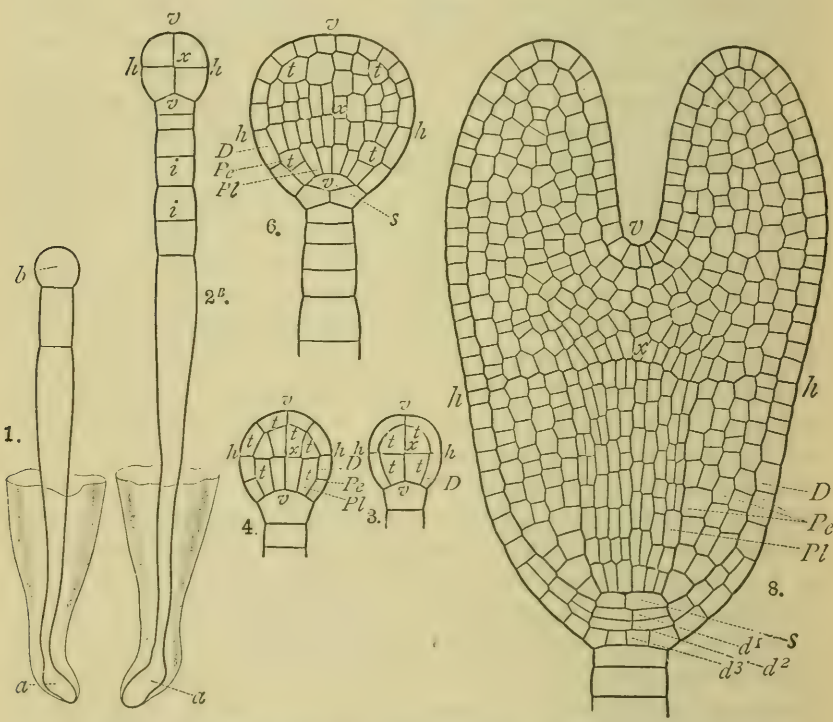


Fig. 936. Successive stages in development of the embryo of *Brassica*. After Kny.

MONOCOTYLEDONS.—The embryo has a single cotyledon, which is placed at its apex, while the plumule arises laterally; the flower is usually trimerous; the vascular bundles do not contain cambium and are small and arranged in a scattered manner in the stele; the foliage leaves usually have parallel venation.

DICOTYLEDONS.—The embryo has two cotyledons, between

which the plumule is developed; the vascular bundles are arranged in a circle in the stele and usually increase in thick-

Fig. 937.

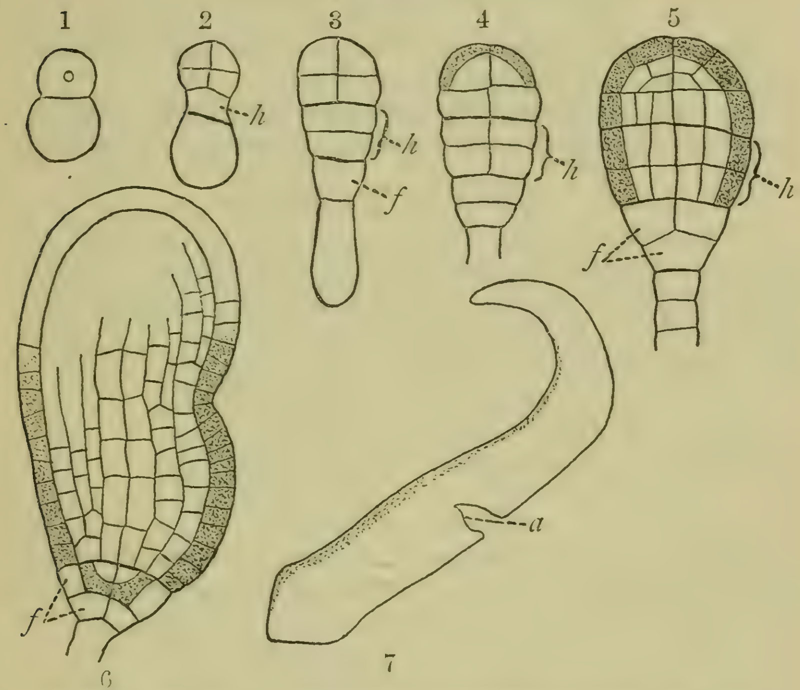


Fig. 937. 1, 2, 3, 4, 5, 6. Successive stages in the development of the Monocotyledonous embryo of *Alisma*. *h.* Hypophysis and the cells derived from it. *f.* Segment of the hypophysis which gives rise to the root. 7. Mature embryo. *a.* Apex of stem. After Sachs.

ness by means of a cambium layer; the flower is either tetramerous or pentamerous; the foliage leaves usually have reticulate venation.

Class X.—MONOCOTYLEDONES.

The general histology as well as the morphology of this group has been already treated of in some detail.

The class is divided by Bentham and Hooker into the following seven series, each including several natural orders.

Series 1.—*Microspermæ.*

Characters.—At least the inner whorl of the perianth petaloid. Ovary inferior, 1-celled with 3 parietal placentæ, or rarely 3-celled with axile placentæ; seeds very small, numerous, exalbuminous.

Order 1. Hydrocharidaceæ.
2. Burmanniaceæ.
3. Orchidaceæ.
4. Apostasiaceæ.

Series 2.—*Epigynæ.*

Characters.—At least the inner whorl of the perianth petaloid. Ovary inferior, except in a few genera of Bromeliaceæ and Hæmodoraceæ. Albumen copious.

Order 5. Zingiberaceæ or Scitaminaceæ.
6. Marantaceæ or Cannaceæ.
7. Musaceæ.
8. Bromeliaceæ.
9. Hæmodoraceæ.
10. Iridaceæ.
11. Amaryllidaceæ.
12. Taccaciæ.
13. Dioscoriaceæ.

Series 3.—*Coronariæ.*

Characters.—At least the inner whorl of the perianth petaloid. Ovary free, or very slightly adherent at base. Albumen copious.

Order 14. Roxburghiaceæ.
15. Liliaceæ.
16. Philesiaceæ.
17. Melanthaceæ or Colchicaceæ.
18. Smilaceæ.

19. Pontederiaceæ.
20. Philydraceæ.
21. Xyridaceæ.
22. Mayaceæ.
23. Commelynaceæ.

Series 4.—*Calycinæ.*

Characters.—Perianth herbaceous; inner whorl small; very rarely sub-petaloid. Ovary free. Albumen copious.

Order 24. Juncaceæ.
25. Palmaceæ.

Series 5.—*Nudifloræ.*

Characters.—Perianth absent or reduced to scales or setas. Ovary superior with a solitary carpel, or if of many carpels then syncarpous. Ovules 1–∞. Seeds most frequently albuminous.

Order 26. Pandanaceæ.
27. Typhaceæ.
28. Aroidaceæ or Araceæ.
29. Lemnaceæ.

Series 6.—*Apocarpæ.*

Characters.—Perianth uniseriate or absent. Ovary superior. Carpels distinct or solitary. Seeds exalbuminous.

Order 30. Triuridaceæ.
31. Alismaceæ.
32. Butomaceæ.
33. Naiadaceæ.
34. Juncaginaceæ.

Series 7.—*Glumaceæ.*

Characters.—Flowers in capitula or spikelets, disposed under bracts or glumes; very often imbricated, sessile; segments of perianth small, scale-like, glumaceous or absent. Ovary either with one ovule, or divided into monovulate loculi. Seeds albuminous.

Order 35. Eriocaulaceæ.
36. Desvauxiaceæ.
37. Restiaceæ.
38. Cyperaceæ.
39. Graminaceæ.

Series 1.—*Microspermæ.*

Order 1. HYDROCHARIDACEÆ, the Hydrocharis or Frog-bit Order.—Character.—Aquatic plants. *Flowers* spathaceous, regular, unisexual or polygamous. *Perianth* superior, in 1 or 2 whorls, each composed of 3 pieces, the inner petaloid. *Stamens* few or numerous. *Ovary* inferior, usually 1—6-celled; placentation parietal. *Fruit* indehiscent. *Seeds* numerous, exalbuminous.

Distribution, Numbers, and Properties.—Inhabitants of fresh water in Europe, North America, East Indies, and New Holland. *Illustrative Genera*:—Anacharis, *Rich.*; Vallisneria, *Mich.* There are about 25 species. Their properties are unimportant.

Order 2. BURMANNIACEÆ, the Burmannia Order.—Character.—*Herbaceous plants*, without true leaves, or with tufted radical ones. *Flowers* hermaphrodite, regular. *Perianth* petaloid, tubular, regular, superior, usually with 6 divisions. *Stamens* distinct, inserted into the tube of the perianth, either 3 with introrse anthers, and opposite the inner segments of the perianth, or 6 with extrorse anthers. *Ovary* inferior, 1-celled with 3 parietal placentas, or 3-celled with axile placentas; *style* 1; *stigmas* 3. *Fruit* capsular, 1—3-celled. *Seeds* numerous, very minute; *embryo* solid.

Distribution and Numbers.—They are principally found in the tropical parts of Asia, Africa, and America. *Illustrative Genera*:—Burmannia, *Linn.*; Thismia, *Griff.* According to Miers, there are 38 species. Their properties are unimportant, but some are reputed to be bitter and astringent.

Order 3. ORCHIDACEÆ, the Orchis Order.—Character.—*Herbs* or *shrubs*, terrestrial or epiphytical. *Roots* fibrous or tuberculated; no true stem or a pseudo-bulb. *Leaves* entire generally sheathing. *Flowers* irregular, solitary or numerous, with a single bract, hermaphrodite. *Perianth* superior, usually petaloid and composed of six pieces, which are commonly arranged in two whorls; the *outer whorl*, *s*, *sl*, *sl*, formed of three pieces (*sepals*), more or less united below or distinct; one, *s*, being anterior, or when the ovary is twisted posterior, and two, *sl*, *sl*, lateral; the *inner whorl* usually consists of three pieces (*petals*), (or rarely of but one), alternating with the pieces in the outer whorl; one (the *labellum* or *lip*) posterior, or by the twisting of the ovary anterior, usually longer and larger than the other pieces, and altogether different from them in form, often

spurred; sometimes the labellum exhibits a division into three regions, of which the lowest is then termed the *hypochilium*, the middle the *mesochilium*, and the upper the *epichilium*. *Andrœcium* united to the style (*gynandrous*) and forming with it a central column (*gynostemium*); the *column* usually bearing one perfect anther and two lateral abortive ones, or in *Cypripedium* two lateral perfect anthers and one abortive anther in the centre. *Pollen* powdery, or more or less collected into grains or waxy or mealy masses (*pollinia*); the masses free, or

Fig. 938.

Fig. 939.

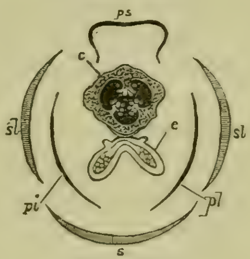


Fig. 940.

Fig. 941.

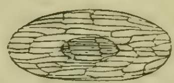


Fig. 938. Front view of the flower of the Tway-blade (*Listera ovata*), showing the bifid labellum at the anterior part of the flower, and the other five divisions of the perianth; the one stamen and three styles forming a column (*gynostemium*).——*Fig.* 939. Diagram of the flower of an Orchid. *s, sl, sl.* The three outer divisions of the perianth; *s* being anterior or inferior, *sl, sl*, being lateral. *pl, pi.* The two lateral divisions of the inner whorl of the perianth. *ps.* The superior or posterior division (*labellum*) of the inner whorl; this by the twisting of the ovary becomes ultimately inferior or anterior. *e.* The fertile stamen, with two anther lobes. *c.* Transverse section of the ovary, with three parietal placentas.——*Fig.* 940. Fruit of an Orchid dehiscing by three valves, each valve bearing a placenta and numerous very minute seeds.——*Fig.* 941. Seed of an Orchid, with a loose reticulated testa.

attached by their stalk, *c* (*caudicle*), to a gland or glands (*retinacula*) at the apex (*rostellum*) of the stigma. *Ovary* inferior, 1-celled, with 3 parietal placentas bearing a number of anatropous ovules; *style* united with the andrœcium and forming with it a column or *gynostemium*; *stigma* a viscid space in front of the column. *Fruit* usually capsular, 3-valved, the valves bearing the placentas in their middle, and separating when the fruit is ripe from the central parts or midribs of the component carpels, which are left as an open framework; or

rarely fleshy and indehiscent. *Seeds* very minute and numerous, with a loose netted or rarely hard crustaceous testa, exalbuminous; *embryo* a fleshy solid mass.

Diagnosis.—This order is readily known by its irregular flowers; by the peculiar form which the labellum in many cases assumes, so as to cause the flower to resemble some insect, reptile, bird, or other living object; by its gynandrous stamens; its frequently more or less coherent pollen; and by its 1-celled inferior ovary with three parietal placentas.

Division of the Order.—This order has been divided by Lindley and others into several tribes, the characters being derived from the number and position of the anthers, the number and nature of the pollen-masses, and other characters; but the description of these does not come within the scope of this volume.

Distribution and Numbers.—They are more or less abundantly distributed in nearly all regions of the globe, except in those which have a very cold or dry climate. Some species are terrestrial and occur chiefly in temperate regions; others are epiphytical and are confined to hot climates. *Illustrative Genera:*—Malaxis, *Swartz*; Dendrobium, *Swartz*; Oncidium, *Swartz*; Stanhopea, *Frost*; Orchis, *Linn.*; Cypripedium, *Linn.* The order contains about 5,000 species, 2,000 being in cultivation.

Properties and Uses.—These plants, which present so much interest from the singularity, beauty, and fragrance of their flowers, are of little importance from an economic or medicinal point of view. Some are aromatic and fragrant, and are used as flavouring agents, several possess nutritious roots, and a few are antispasmodic and aphrodisiac.

Order 4. APOSTASIACEÆ, the Apostasia Order.—Character. *Herbs*, with regular hermaphrodite flowers. *Perianth* superior, regular, with 6 divisions. *Stamens* 2 or 3, united by their filaments with the lower part of the style into a column; *anthers* sessile upon the column, 2 or 3. *Ovary* inferior, 3-celled, with axile placentation; *ovules* numerous; *style* united below with the filaments into a column, but prolonged above into a filiform process. *Capsule* 3-celled, 3-valved. *Seeds* very numerous. *By Bentham and Hooker this order is included in Orchidaceæ.*

Distribution and Numbers.—Natives of damp woods in tropical India. *Illustrative Genus:*—Apostasia, *Blume.* There are about 5 species. Their properties are altogether unknown.

Series 2.—*Epigynæ.*

Order 5. ZINGIBERACEÆ or SCITAMINACEÆ, the Ginger Order.—Character.—Aromatic *herbs*, with creeping rhizomes, and broad simple, stalked, sheathing leaves, with parallel curved veins springing from the midrib. *Flowers* arranged in a spiked or racemose manner, and arising from among spathaceous membranous bracts. *Perianth* superior, irregular, each whorl consisting of 3 pieces. *Stamens* 6, in 2 whorls, all abortive except the posterior one of the inner whorl; *anther* 2-celled; *filament* not petaloid. *Ovary* inferior, 3-celled; *placentas* axile; *style* filiform. *Fruit* 1—3-celled, capsular or baccate. *Seeds* numerous, albuminous; *embryo* enclosed in endosperm.

By Bentham and Hooker the two succeeding orders, Marantaceæ and Musaceæ, are included in Zingiberaceæ.

Distribution and Numbers.—Chiefly natives of tropical regions. *Illustrative Genera*:—Zingiber, *Gärtn.*; Curcuma, *Linn.*; Elettaria, *Rheed.* There are about 250 species.

Properties and Uses.—They are principally remarkable for the stimulant aromatic properties possessed by their rhizomes and seeds, owing to the presence of resins and volatile oils; hence several are used as condiments, and in medicine as aromatic stimulants and stomachics. Some contain starch in large quantities, which when extracted is employed for food.

Order 6. MARANTACEÆ or CANNACEÆ, the Maranta Order.—Character.—*Herbaceous plants*, without aromatic properties. They have a close resemblance to the Zingiberaceæ. Their distinctive characters are, in their more irregular perianth; in one of the lateral stamens of the inner whorl being fertile, and the other two abortive; in the fertile stamen having a petaloid filament, an entire or 2-lobed anther, one lobe of which is sterile, and the anther therefore 1-celled; in the style being petaloid or swollen; and in the embryo not being enclosed in endosperm.

Distribution and Numbers.—Exclusively natives of tropical regions. *Illustrative Genera*:—Maranta, *Plum.*; Canna, *Linn.* There are about 160 species.

Properties and Uses.—The rhizomes of some species contain starch, which when extracted is extensively used for food.

Order 7. MUSACEÆ, the Banana Order.—Character.—*Herbaceous plants*, often of large size. *Leaves* large, with

parallel curved veins springing from the midribs, and long sheathing petioles, which together form by their union a spurious aerial stem. *Flowers* irregular, spathaceous. *Perianth* irregular, 6-partite, petaloid, superior, arranged in 2 whorls. *Stamens* 6, inserted upon the divisions of the perianth, some abortive; *anthers* 2-celled. *Ovary* inferior, 3-celled. *Fruit* capsular, dehiscing loculicidally, or succulent and indehiscent, 3-celled. *Seeds* usually numerous, rarely 3, without endosperm.

Distribution and Numbers.—Generally diffused throughout tropical and sub-tropical regions. *Illustrative Genera:*—Musa, *Tourn.*; Ravenala, *Adans.* There are about 20 species.

Properties and Uses.—The fruits of some species and varieties form important articles of food in tropical regions. Others yield valuable textile materials; and the large leaves of many are used for various purposes, such as to form a kind of cloth, and as thatching for cottages, &c. The seeds and fruits of others are used as dyeing agents in some countries.

Order 8. BROMELIACEÆ, the Bromelia Order.—Character.—*Herbs* or somewhat *woody plants*, commonly epiphytical. *Leaves* persistent, crowded, channelled, rigid, sheathing at the base, and frequently scurfy and with spiny margins. *Flowers* showy. *Perianth* regular, superior, or nearly or quite inferior, arranged in two whorls, the outer of which has its parts commonly united into a tube; and the inner has its parts distinct, imbricate, and of a different colour from those of the outer whorl. *Stamens* 6; *anthers* introrse. *Ovary* 3-celled; *style* 1. *Fruit* capsular or indehiscent. *Seeds* numerous; *embryo* minute, at the base of mealy albumen, with the radicle next the hilum.

Distribution and Numbers.—They are mostly found in the tropical regions of America, West Africa, and the East Indies. They appear to have been originally natives of America and the adjoining islands, but are now naturalised in West Africa and the East Indies. *Illustrative Genera:*—Ananassa, *Lindl.*; Tillandsia, *Linn.* There are about 180 species.

Properties and Uses.—They are chiefly important for yielding edible fruits and useful fibrous materials. Some are anthelmintic, and others contain colouring matters.

Order 9. HÆMODORACEÆ, the Blood-root Order.—Character.—*Herbs* or rarely *shrubs*, with fibrous roots. *Leaves* usually equitant, ensiform. *Perianth* more or less superior, tubular, 6-partite, regular, the divisions usually scurfy or woolly on their outside *Stamens* 3 or 6 when 3 they are opposite the inner

segments of the perianth; *anthers* introrse. *Ovary* inferior, or partially so, 3-celled. *Fruit* dehiscent or indehiscent, covered by the withered perianth. *Seeds* few or numerous, with cartilaginous albumen, and radicle remote from the hilum.

Distribution and Numbers.—Natives of America, the Cape of Good Hope, and Australia. *Illustrative Genera*:—Hæmodorum, *Smith*; Vellozia, *Mart.* There are about 50 species.

Properties and Uses.—The roots of some species are used as dyeing agents in North America, others are edible, and a few are bitter and astringent.

Order 10. IRIDACEÆ, the Iris Order.—Character.—*Herbs*, usually with bulbs, corms, or rhizomes. *Leaves* with parallel venation, generally equitant. *Flowers* spathaceous. *Perianth* superior, petaloid, 6-partite, in two whorls, which are equal or nearly so, or unequal, in the size of their segments; or sometimes the parts are entirely distinct; convolute in æstivation. *Stamens* 3, inserted on the outer segments of the perianth; *anthers* 2-celled, innate, extrorse. *Ovary* inferior, 3-celled with axile placentation; *style* 1; *stigmas* 3, often petaloid. *Fruit* capsular, 3-celled, 3-valved, with loculicidal dehiscence. *Seeds* numerous with horny or fleshy albumen.

Diagnosis.—Herbs. Leaves with parallel veins. Flowers on scapes, spathaceous. Perianth petaloid, superior, 6-partite, or rarely the parts are quite distinct, in two equal or unequal whorls. Stamens 3, distinct or monadelphous; anthers innate, extrorse. Ovary 3-celled, with axile placentation, inferior. Fruit capsular, with loculicidal dehiscence, 3-celled, 3-valved. Seeds numerous, albuminous.

Distribution and Numbers.—Chiefly natives of temperate and warm climates. They are found in various parts of the globe, but are most abundant at the Cape of Good Hope. *Illustrative Genera*:—Iris, *Linn.*; Gladiolus, *Tourn.*; Crocus, *Linn.* There are about 560 species.

Properties and Uses.—The rhizomes of several species possess acrid properties, which causes them to be purgative, emetic, &c. Some are poisonous, and a few have fragrant rhizomes. Others are employed as colouring agents, and some are commonly regarded as antispasmodic, carminative, &c. Many contain starch in large quantities, but as this is usually combined with acridity, they are not generally available for food, although some are stated to be thus employed in Africa.

Order 11. AMARYLLIDACEÆ, the Amaryllis Order.—Cha-

racter.—Bulbous or fibrous-rooted plants, without any aerial stem, or sometimes with a woody one. *Leaves* with parallel venation, and usually linear-ensiform, sometimes dry and harsh.

FIG. 942.

FIG. 943.

FIG. 944.

FIG. 946.

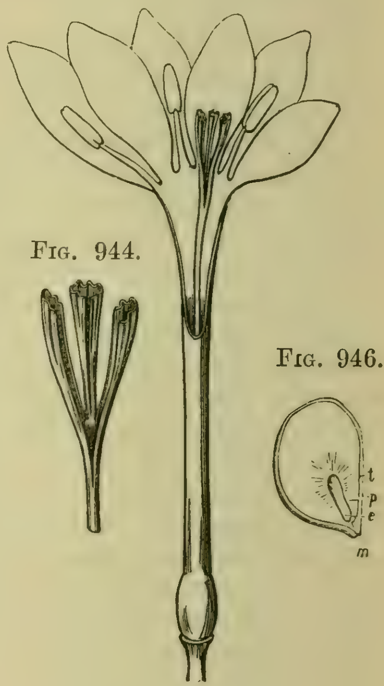


FIG. 945.

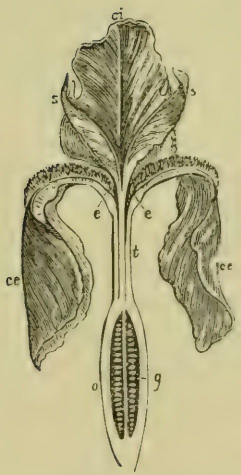


Fig. 942. Diagram of the flower of a species of *Iris*, showing solitary bract below, six divisions to the perianth arranged in two whorls, three stamens, and a three-celled ovary with axile placentation.——*Fig*. 943. A flower of the Spring Crocus (*Crocus vernus*) cut open to show the three extrorse stamens attached to the outer segments of the perianth.——*Fig*. 944. The three petaloid stigmas of the same with the end of the style. ——*Fig*. 945. Vertical section of the flower of *Iris germanica*. *ce, ce*. Two of the external and larger divisions of the perianth. *ci*. One of the internal and smaller divisions. *t*. Tube formed by the union of the divisions of the perianth. *e, e*. Stamens, covered by the petaloid stigmas, *s, s*. *o*. Inferior ovary, with numerous ovules, *g*, attached to placentas in the axis. ——*Fig*. 946. Vertical section of the seed of the same. *t*. Integuments of the seed. *p*. Albumen. *e*. Embryo. *m*. Micropyle. From Jussieu.

Flowers usually on scapes, and spathaceous. *Perianth* regular or nearly so, petaloid, superior with six divisions, and with or without a corona; æstivation imbricate or valvate. *Stamens* 6,

inserted on the perianth or summit of the ovary; *anthers* 2-celled, introrse. *Ovary* inferior; 3-celled; *placentas* axile. Fruit capsular, 3-celled, 3-valved, with loculicidal dehiscence and numerous seeds; or baccate, with 1—3 seeds. *Seeds* with fleshy or horny albumen, sometimes carunculate; *embryo* with the radicle turned to, or remote from, the hilum.

FIG. 947.

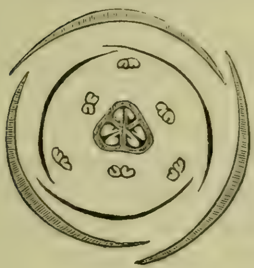


FIG. 948.

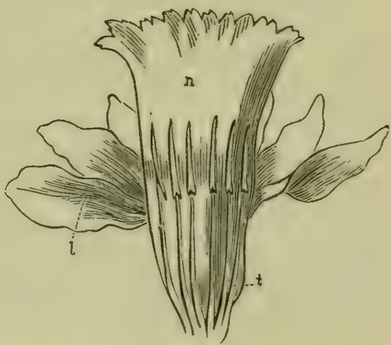


FIG. 949.

FIG. 950.

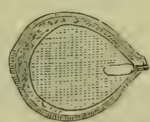


Fig. 947. Diagram of the flower of the Spring Snowflake (*Amaryllidaceæ*), with six divisions to the perianth arranged in two whorls, six stamens, and a 3-celled ovary with axile placentation.——*Fig.* 948. The perianth of the Daffodil (*Narcissus Pseudo-narcissus*) cut open in a vertical manner. *t.* Tube bearing six stamens. *l.* Limb of the perianth. *n.* Corona.——*Fig.* 949. Vertical section of the flower of the Spring Snowflake (*Leucojum vernum*).——*Fig.* 950. Vertical section of the seed of the same.

Diagnosis.—Leaves with parallel veins. Flowers spathaceous. Perianth superior, petaloid, commonly regular, 6-partite, frequently with a corona. Stamens 6; anthers introrse. Ovary inferior, 3-celled, with axile placentation. Fruit capsular, 3-valved, with loculicidal dehiscence, or baccate. Seeds numerous, albuminous.

Distribution and Numbers.—Natives of many parts of the world, but, like the Iridaceæ, most abundant at the Cape of

Good Hope. *Illustrative Genera:*—Galanthus, *Linn.*; Amaryllis, *Linn.*; Narcissus, *Linn.*; Agave, *Linn.*; Hypoxis, *Linn.* There are above 460 species.

Properties and Uses.—Several plants of this order possess poisonous qualities. This property is especially evident in *Hæmanthus toxicarius*, the juice of which is used by the Hottentots to poison their arrow-heads. Some yield excellent fibres. The juice of some few species is saccharine, and is employed in the preparation of fermented liquors. Starch may be obtained from certain species of *Alstrœmeria*. Some are bitter and aromatic. Medicinally, several have been used as emetics and purgatives.

Order 12. TACCACEÆ, the Tacca Order.—Character.—Perennial *herbs*, with fleshy roots. *Leaves* large, with parallel veins, radical, stalked. *Flowers* hermaphrodite. *Perianth* tubular, regular, 6-partite, superior. *Stamens* 6, inserted into the base of the divisions of the perianth, with petaloid filaments, incurved and hooded at the apex; *anthers* 2-celled, placed in the concavity below the apex of the filaments. *Ovary* inferior, 1-celled, with 3 parietal placentas projecting more or less into the interior; *styles* 3. *Fruit* baccate. *Seeds* numerous, with fleshy albumen.

Distribution and Numbers.—Natives of mountainous regions in India, the Malayan Archipelago, the Philippines, Australia, Polynesia, Madagascar, Guiana. According to Hance, there are three genera—Tacca, *Forst.*; Ataccia, *J. S. Presl*; and Schizocapsa, *Hance*—which contain twelve or more species.

Properties and Uses.—The roots are bitter and acrid, but when cultivated they become larger and lose in some degree their acridity and bitterness, and contain much starch, which when separated is used for food.

Order 13. DIOSCOREACEÆ, the Yam Order.—Character.—Climbing *herbs*, or small *shrubs*, with twining stems rising from tuberous rootstocks or tubers, placed above or under the ground. *Leaves* net-veined, stalked. *Flowers* unisexual, diœcious, small, bracteate. *Male flower*:—*Perianth* 6-cleft. *Stamens* 6, inserted at the base of the perianth-segments. *Female flower*:—*Perianth* superior, 6-partite. *Stamens* sometimes present, but very short and abortive. *Ovary* inferior, 3-celled; *styles* 3, distinct, or 1, and then deeply trifid; *ovules* 1—2 in each cell, suspended. *Fruit* dehiscent and compressed, or

fleshy and indehiscent, 1—3-celled. *Seeds* albuminous; *embryo* small, in a cavity in the albumen.

Distribution and Numbers.—Chiefly tropical plants. *Tamus communis* is, however, found in Britain and other temperate regions. *Illustrative Genera:*—Tamus, *Linn.*; Dioscorea, *Linn.* There are above 150 species.

Properties and Uses.—The plants generally contain an acrid principle. The tuberous rootstocks of many species of *Dioscorea* are, however, when boiled, used for food in tropical countries.

Series 3.—*Coronariæ.*

Order 14. ROXBURGHIACEÆ, the Roxburghia Order.—Character.—Twining *shrubs* with tuberous roots. *Leaves* net-veined, leathery, broad. *Flowers* large and showy, solitary, hermaphrodite. *Perianth* inferior, with 4 petaloid divisions. *Stamens* 4, hypogynous, with enlarged connectives; *anthers* introrse, apicilar. *Ovary* superior, 1-celled, with a basal placenta; *stigma* sessile. *Fruit* 2-valved, 1-celled. *Seeds* numerous, in 2 stalked clusters, anatropous; *embryo* in the axis of fleshy albumen.

Distribution, Numbers, and Properties.—They are natives of the hotter parts of the East Indies. There is but one genus, Roxburghia, *Dryand.*, which includes 4 species. Their properties are unimportant.

Order 15. LILIACEÆ, the Lily Order.—Character.—*Herbs*, *shrubs*, or *trees*, with bulbs, rhizomes, tubers, or fibrous roots. *Stem* simple or branched. *Leaves* with parallel or rarely reticulated veins, sessile or sheathing, sometimes succulent. *Flowers* regular, variously arranged or solitary. *Perianth* green or petaloid, inferior, usually regular and 6-leaved or 6-partite. *Stamens* 6, or rarely more, or 3 in *Ruscus*, inserted on the perianth, or rarely on the thalamus: *anthers* introrse. *Ovary* superior, 3-celled, or very rarely 4—6-celled, with numerous ovules on axile placentas; *style* 1, or very rarely 3 or more, or absent; *stigma* generally simple or 3-lobed. *Fruit* a loculicidal capsule, or succulent and indehiscent, usually 3-celled. *Seeds* with fleshy albumen, numerous.

Diagnosis.—Leaves with usually parallel straight veins, or succulent. Perianth inferior, generally 6-leaved or 6-partite, and regular. Stamens 6, or rarely more, or 3 in *Ruscus*; anthers introrse. Ovary superior, with axile placentation: style 1, usually undivided, or very rarely divided, and sometimes

absent. Fruit indehiscent or a loculicidal capsule. Seeds numerous, albuminous.

Division of the Order and Illustrative Genera:—This order has been divided by Baker into three tribes as follows:—

Fig. 951.

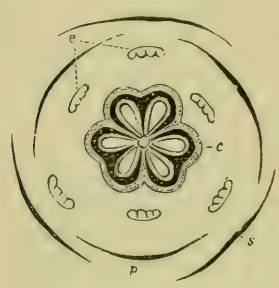


Fig. 952.

Fig. 954.

Fig. 953.

Fig. 956.

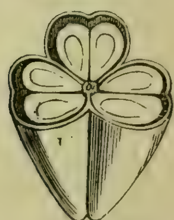


Fig. 955.

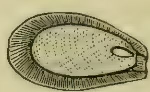


Fig. 951. Diagram of the flower of a species of Lily. *s.* The three outer divisions of the perianth. *p.* The three inner. *e.* The stamens. *c.* Three-celled ovary.——*Fig.* 952. Raceme of flowers *f*, and portion of the succulent leaf *l*, of a species of *Aloe.*——*Fig.* 953. Flower of the Crown Imperial (*Fritillaria imperialis*) with half the perianth removed.——*Fig.* 954. Vertical section of the flower of the Solomon's Seal (*Polygonatum multiflorum*).——*Fig.* 955. Transverse section of the ovary of the White Lily (*Lilium candidum*).——*Fig.* 956. Vertical section of the seed of the Crown Imperial.

Tribe 1. *Lilieæ.*—Anthers introrse. Styles united. Fruit a loculicidal capsule. *Illustrative Genera:*—Lilium, *Linn.*; Tulipa, *Linn.*; Scilla, *Linn.*

Tribe 2. *Colchiceæ.*—Anthers extrorse. Styles separate. Fruit

a septicidal capsule. *This tribe forms the order Melanthaceæ or Colchicaceæ of this volume.*

Tribe 3. *Asparageæ.*—Fruit baccate. *Illustrative Genera* :—Asparagus, *Linn.*; Convallaria, *Linn.*

By Bentham and Hooker this order has been divided into 20 tribes arranged in 3 series, and includes the Colchicaceæ, Smilaceæ, and Philesiaceæ of this volume.

Distribution and Numbers.—They are widely distributed throughout the temperate, warm, and tropical regions of the globe. There are over 1,360 species.

Properties and Uses.—The plants of this order frequently possess important properties, but there is no great uniformity in them. Some are purgative; others emetic, diuretic, diaphoretic, stimulant, acrid, &c. Several yield astringent substances, and many produce valuable fibres. The bulbs, young shoots, roots, and seeds of others are highly esteemed, and largely consumed as articles of food and condiments.

Order 16. PHILESIACEÆ, the Philesia Order.—*Diagnosis, &c.*—The plants of this order are closely allied to the Roxburghiaceæ, from which, however, they are readily distinguished by their hexamerous perianth and andrœcium, perigynous stamens, parietal placentation, long style, and semi-anatropous ovules. They are natives of Chili. There are 2 genera—Philesia, *Commers.*; and Lapageria. *R. et P.*—and 2 species. In their properties they are said to resemble Sarsaparilla. (See *Smilax.*) *This order is included in Liliaceæ by Bentham and Hooker.*

Order 17. COLCHICACEÆ, or MELANTHACEÆ.—The Colchicum Order.—Character.—*Herbs*, with bulbs, corms, tubers, or fibrous roots. *Flowers* regular, usually hermaphrodite, or rarely unisexual. *Perianth* inferior, white, green, or purple, 6-partite or 6-leaved. *Stamens* 6, *anthers* extrorse. *Ovary* superior or nearly so, 3-celled, with axile placentation; *style* 3-partite; *stigmas* 3. *Fruit* 3-celled, 3-valved, with usually septicidal dehiscence. *Seeds* numerous; *embryo* minute, in fleshy albumen.

By Bentham and Hooker the plants of this order (see Liliaceæ) are now placed, according to the views of Baker, in the Liliaceæ.

Diagnosis.—Herbs. Flowers regular, hermaphrodite or rarely unisexual. Perianth inferior, 6-partite or 6-leaved. Stamens 6; anthers extrorse. Ovary superior; style 3-partite.

Fruit a septicidal or very rarely a loculicidal capsule, 3-celled, 3-valved, membranous. Seeds numerous, albuminous.

Distribution and Numbers.—Generally diffused, but most abundant in Europe, North America, and the northern parts of Asia. *Illustrative Genera :*—Colchicum, *Linn.*; Tofieldia, *Hudson.* There are about 150 species.

Properties and Uses.—The plants of this order are almost universally poisonous, owing to the presence of powerful alkaloids. But in proper doses several are valuable medicines, pos-

FIG. 957.

FIG. 958.

FIG. 959.

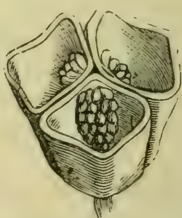


FIG. 960.

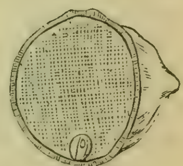


Fig. 957. Flowering plant of the Colchicum or Meadow Saffron (*Colchicum autumnale*).——*Fig.* 958. Diagram of the flower of the same, with six divisions to the perianth arranged in two whorls, six stamens, and a 3-celled ovary.——*Fig.* 959. Transverse section of the capsule.——*Fig.* 960. Vertical section of the seed.

sessing emetic, purgative, diuretic, acrid, and narcotic properties.

Order 18. SMILACEÆ, the Sarsaparilla Order.—Character.—*Herbs* or *shrubs*, more or less climbing. *Leaves* petiolate, net-veined, articulated. *Flowers* regular, unisexual and diœcious, or hermaphrodite. *Perianth* inferior, 6-partite, with all its divisions alike. *Stamens* 6, perigynous or rarely hypogynous; *anthers* introrse. *Ovary* superior, 3- 5- or rarely 1-celled, with orthotropous ovules; *stigmas* 3. *Fruit* baccate, few or many-seeded. *Seeds* with a minute embryo, in hard albumen. *This*

order, as we have already noticed, is included in Liliaceæ by Bentham and Hooker.

Distribution and Numbers.—The species of this order are scattered over various parts of the world, both in tropical and temperate climates; they are, however, most abundant in tropical America. *Illustrative Genera*:—Smilax, *Linn.*; Ripogonum, *Forst.* These are the only genera; there are probably about 120 species, but some botanists make the number considerably more.

Properties and Uses.—The plants of this order generally possess alterative properties.

Order 19. PONTEDERIACEÆ, the Pontederia Order.—Character.—Aquatic *herbs*. *Leaves* sheathing at the base, with occasionally dilated petioles. *Flowers* hermaphrodite, irregular, spathaceous. *Perianth* inferior, 6-partite, petaloid, tubular, persistent, rolling inwards after flowering. *Stamens* 3 or 6, inserted on the segments of the perianth; *anthers* introrse. *Ovary* superior; *style* 1; *stigma* simple. *Fruit* capsular, occasionally somewhat adherent to the persistent perianth. *Seeds* numerous, with mealy albumen.

FIG. 961.

Fig. 961. Portion of a branch, with leaves and fruit, of *Smilax papyracea.*

Distribution, Numbers, and Properties.—They are natives of the East Indies, Africa, and America. *Illustrative Genera*:—Leptanthus, *L. C. R.*; Pontederia, *Linn.* There are above 30 species. Their properties are unimportant.

Order 20. PHILYDRACEÆ, the Water-wort Order.—Charac-

ter.—*Herbs*, with fibrous roots. *Leaves* equitant, ensiform sheathing. *Flowers* surrounded by a spathaceous persistent bract, hermaphrodite. *Perianth* inferior, 3-partite, petaloid, the two upper segments united so that it appears to consist of 2 segments. *Stamens* 3, 2 of which are barren and petaloid, and all united to the anterior lobe of the perianth; *pollen* united in masses of four. *Ovary* superior, 3-celled, with axile placentas; *style* simple; *stigma* capitate. *Fruit* a loculicidal capsule. *Seeds* numerous, with an embryo in the axis of fleshy albumen.

Distribution, Numbers, and Properties.—They are natives of China, Cochin China, and Australia. There are 2 genera (Philydrum, *Banks*, and Hetæria, *Endl.*) and 2 species. Their properties and uses are unknown.

Order 21. XYRIDACEÆ, the Xyris Order.—Character.—Sedge-like *herbs*. *Leaves* radical, sheathing, ensiform or filiform. *Flowers* hermaphrodite, in scaly heads. *Perianth* inferior, 6-partite, arranged in two whorls,—the outer sub-glumaceous or scaly, distinct, and opposite the carpels; the inner petaloid, regular, and united. *Stamens* 3, inserted into the base of the outer lobes of the perianth, or sometimes 6; *anthers* 2-celled, extrorse. *Ovary* superior, 1-celled, with parietal placentas. *Capsule* 1-celled, 3-valved. *Seeds* numerous; *embryo* minute, in fleshy or mealy albumen.

The genus Rapatea is sometimes made the type of a distinct order—Rapateaceæ.

Distribution and Numbers.—Exclusively natives of tropical and sub-tropical regions. *Illustrative Genera*:—Xyris, *Linn.*; Rapatea, *Aubl.* There are about 70 species.

Properties and Uses.—Unimportant. The leaves and roots of some species of *Xyris* have been employed in cutaneous affections.

Order 22. MAYACEÆ, the Mayaca Order.—*Diagnosis.*—Small Moss-like plants growing in damp places. They are closely allied to Commelynaceæ, from which they differ in their habit; their 1-celled anthers; their 1-celled ovary and capsule with parietal placentas; and in their carpels being alternate to the outer segments of the perianth.

Distribution, Numbers, and Properties.—They are found in America from Brazil to Virginia. *Mayaca*, Aubl., is the only genus, of which there are 4 species. Their properties and uses are unknown.

Order 23. COMMELYNACEÆ, the Spiderwort Order.—Cha-

racter.—*Herbs*, with flattened, narrow, usually sheathing *leaves*. *Perianth* inferior, more or less irregular, in six parts arranged in two whorls; the outer parts being green, persistent, and opposite to the carpels; the inner petaloid. *Stamens* 3 or 6, some generally abortive, hypogynous; *anthers* 2-celled, introrse. *Ovary* 3-celled, superior; *style* 1. *Capsule* 2—3-celled, 2—3-valved, with loculicidal dehiscence and axile placentation. *Seeds* few, with a linear hilum; *embryo* shaped like a pulley, remote from the hilum, in dense fleshy albumen.

Distribution and Numbers.—They are chiefly natives of India, Africa, Australia, and the West Indies. *Illustrative Genera*:—Commelyna, *Dill.*; Tradescantia, *Linn.* There are above 260 species.

Properties and Uses.—Their properties are unimportant.

FIG. 962.

FIG. 963.

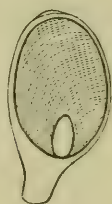


Fig. 962. Flower of a species of Wood-rush (*Luzula*), having an inferior perianth with six divisions, 6 stamens, and a superior ovary with 1 style and 3 stigmas.——*Fig.* 963. Vertical section of the seed of the same.

The rhizomes of some species, as those of *Commelyna tuberosa*, *C. angustifolia*, and *C. striata*, contain much starch, and when cooked are edible. Others have been reputed astringent and vulnerary, and some emmenagogue, &c.

Series 4.—*Calycinæ.*

Order 24. JUNCACEÆ, the Rush Order.—Character.—Sedge- or grass-like *herbs*, rhizomatous or with tufted or fibrous roots. *Leaves* with parallel veins, fistular or more or less flattened and grooved. *Flowers* regular. *Perianth* inferior, 6-partite, scale-like or coriaceous, greenish or brown, persistent. *Stamens* 6, or rarely 3, perigynous; *anthers* introrse, 2-celled. *Ovary* superior, 1—3-celled; *style* 1, *stigmas* 3 or 1. *Fruit* a loculicidal capsule, 3-celled, 3-valved, and with 1 or many seeds

in each cell; rarely 1-celled, 1-seeded, and indehiscent; *embryo* very minute, in fleshy or horny albumen; *radicle* inferior.

Distribution and Numbers.—A few are found in tropical regions, but most of the order inhabit cold and temperate climates. *Illustrative Genera:*—Juncus, *DC.*; Luzula, *DC.* There are about 200 species.

Fig. 964.

Fig. 965.

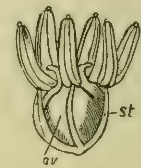


Fig. 966.

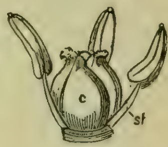


Fig. 967.

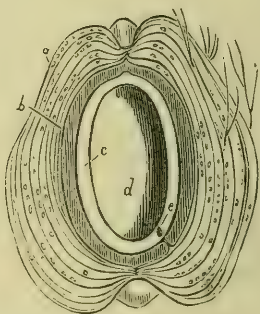


Fig. 968.

Fig. 969.

Fig. 964. Diagram of a staminate flower of the Fan Palm (*Chamærops*), with six divisions to the perianth, and six stamens.——*Fig.* 965. Diagram of a pistillate flower of the same, with six divisions to the perianth, and a 3-celled ovary.——*Fig.* 966. Hermaphrodite flower of the Blue Palmetto (*Chamærops hystrix*), with the perianth removed. *ov.* Carpels. *st.* Stamens.——*Fig.* 967. The same, with three of the stamens removed, so as to exhibit more completely the three carpels composing the pistil. *st.* Stamens. *c.* Carpels.——*Fig.* 968. Vertical section of the fruit of the Cocoa-nut Palm (*Cocos nucifera*). *a.* The two outer layers or husk of the pericarp. *b.* Endocarp or inner layer. *c.* Albumen. *d.* Cavity in the albumen. *e.* Embryo.——*Fig.* 969. Vertical section of the seed of the Fan Palm.

Properties and Uses.—Their medicinal properties are unimportant, although some have a reputation as anthelmintics and diuretics.

Order 25. PALMACEÆ, the Palm Order.—Character.—*Trees* or *shrubs*, with simple unbranched, or rarely dichotomously branched trunks. *Leaves* terminal, large, mostly compound, with sheathing stalks. *Flowers* hermaphrodite or unisexual,

arranged generally on a branched spadix, which is enclosed by a spathe. *Perianth* usually green, inferior, in two whorls, each of which is composed of three parts. *Stamens* usually 6, hypogynous or perigynous. Carpels 1—3, generally united, but sometimes distinct; *ovary* superior; *ovules* solitary, or rarely 2. *Fruit* nut-like, baccate, or drupaceous. *Seeds* with a minute embryo, in a pit of the albumen; *albumen* fleshy or horny, often ruminated.

Distribution and Numbers.—Most of the plants are tropical, but a few occur in temperate regions. *Illustrative Genera:*—Areca, *Linn.*; Chamærops, *Linn.*; Attalea, *Humb.*; Cocos, *Linn.* There are above 600 species.

Properties and Uses.—Of all orders of plants there is none, with the exception of that of the Grasses, so valuable to man, as regards their dietetical and economic applications, as the Palm Order. These plants supply him with sugar, starch, oil, wax, wine, resin, astringent matters, and also edible fruits and seeds. Their terminal leaf-buds, when boiled, are eaten as a vegetable. Their leaves are applied in various ways, as for thatching, materials for writing upon, and in the manufacture of hats, matting, &c.; their wood is applied to many useful purposes; the fibres of their petioles and fruits supply materials for cordage, cloth, and various other textile fabrics; and the hard albumen of their seeds is applicable in many ways.

Series 5.—*Nudifloræ.*

Order 26. PANDANACEÆ, the Screw-pine Order.—Character.—Palm-like *trees* or *shrubs*. *Leaves* amplexicaul, linear-lanceolate, and then imbricate, and spirally arranged in 3 rows; or pinnated or fan-shaped. *Flowers* unisexual or polygamous, numerous, arranged on a simple or branched spadix, with many spathaceous bracts. *Perianth* absent or scaly. *Stamens* numerous; *anthers* 2—4-celled. *Ovaries* 1-celled; *ovules* solitary or numerous, on parietal placentas. *Fruit* consisting of a number of 1-seeded fibrous drupaceous carpels, or baccate, and many-celled, and many-seeded. *Embryo* minute, embedded at the side near the base of fleshy albumen. *By Bentham and Hooker this order is separated into two orders, the Pandanaceæ and the Cyclanthaceæ.*

Distribution and Numbers.—Exclusively tropical plants. *Illustrative Genera:*—Pandanus, *Linn. fil.*; Carludovica, *R. et P.* There are about 75 species.

Properties and Uses.—None possess any very active properties.

Order 27. TYPHACEÆ, the Bulrush Order.—Character.—*Herbs* growing in watery places. *Leaves* rigid, linear, sessile, parallel-veined. *Flowers* monœcious, arranged on a spadix, or in heads, without a spathe. No true *perianth*, merely scales or hairs. *Male flower* with 1—6 distinct or monadelphous *stamens*, with long *filaments*, and innate *anthers*. *Female*

FIG. 970.

FIG. 971.

FIG. 972.

FIG. 973.

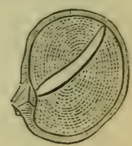


Fig. 970. A plant of the Cuckoo-pint (*Arum maculatum*) in fruit. *b.* Corm. *l.* Leaf. *s.* The remains of the spathe. *c.* Fruit.——*Fig.* 971. The spadix of the same with the spathe removed; the flowers are all naked and unisexual, a number of pistillate flowers or ovaries being below; above which are some rudimentary ovaries, then a number of sessile anthers, and above these are some staminodes or abortive stamens.——*Fig.* 972. Vertical section of the ovary of the same.——*Fig.* 973. Vertical section of the seed.

flower a solitary 1-*celled carpel*, with a single pendulous *ovule*. *Fruit* indehiscent. *Seed* with mealy albumen; *embryo* axile; *radicle* next the hilum.

Distribution and Numbers.—A few are found in tropical and warm climates, but they are most abundant in the northern parts of the world. *Illustrative Genera:*—Typha, *Linn.*; Sparganium, *Linn.* These are the only genera; they include about 13 species.

Properties and Uses.—Unimportant.

Order 28. AROIDACEÆ, the Arum Order.—Character.—*Herbs* or *shrubs*, with commonly an acrid juice, and subterranean tubers, corms, or rhizomes. *Leaves* sheathing, usually net-veined, simple or rarely compound. *Flowers* unisexual and monœcious, or hermaphrodite, arranged on a spadix within a spathe, or the spathe is absent. *Perianth* none, or composed of scales which are inferior. *Male flower:—Stamens* few or numerous; *anthers* extrorse, sessile or upon very short filaments. *Female flower:—Ovary* 1- or more-celled, superior. *Fruit* succulent. *Seeds* pulpy, with abundant mealy, horny, or fleshy albumen, or rarely exalbuminous; *embryo* various.

Diagnosis.—Flowers on a spadix, and with or without a true spathe. Flowers naked, unisexual and monœcious; or hermaphrodite, and then frequently with a scaly inferior perianth. Anthers extrorse. Fruit succulent.

Division of the Order and Illustrative Genera.—The order may be divided into two sub-orders as follows:—

Sub-order 1. *Aroideæ* or *Araceæ.*—Flowers unisexual, monœcious. Spadix surrounded by a spathe. Perianth none. *Illustrative Genera:*—Arum, *Linn.*; Caladium, *Vent.*

Sub-order 2. *Acoreæ* or *Orontieæ.*—Flowers hermaphrodite. Spadix surrounded by a spathe or naked. Perianth absent, or more generally present, and then scaly. *Illustrative Genera:*—Acorus, *Linn.*; Orontium, *Linn.*

Distribution and Numbers.—They abound in tropical countries, but also occur in cold and temperate regions. There are about 250 species.

Properties and Uses.—The plants of this order are all more or less acrid, and often highly poisonous. But this acrid principle is frequently volatile, or decomposed by heat; hence it may be in some cases more or less destroyed by drying or exposing to heat the parts in which it is found. The best method of getting rid of the acridity is, however, by boiling in water, as the acrid matter is also commonly soluble in that fluid. Starch is usually associated with the acrid principle, and when extracted, may be used for food like other starches. The underground stems or corms of many species, when cooked, are eaten in different parts of the world. Some are aromatic stimulants; others expectorant, antispasmodic, or diaphoretic.

Order 29. LEMNACEÆ, the Duckweed Order.—Character.—Floating aquatic plants, with lenticular or lobed leaves or fronds. *Flowers* 2 or 3, enclosed in a spathe (*fig.* 974),

monœcious, placed on the margin or surface of the frond, or in the axils of leaves. *Perianth* none. *Male flower* with 1 or a few stamens, which are often monadelphous. *Female flower* consisting of a 1-celled ovary, with 1 or more erect ovules. *Fruit* 1- or more-seeded, membranous or baccate, indehiscent or sometimes dehiscent. *Embryo* straight, cleft, in the axis of fleshy albumen.

Distribution, Numbers, and Properties.—They inhabit cool,

FIG. 974.

FIG. 975.

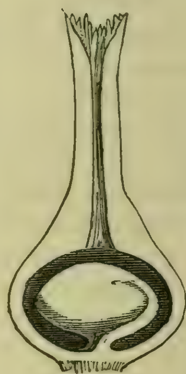


Fig. 974. A monœcious head of flowers of a species of Duckweed (*Lemna minor*), consisting of two male flowers, each of which is composed of a solitary stamen with a quadrilocular anther; and one pistillate flower in the centre; the whole surrounded by a spathe.——*Fig.* 975. Vertical section of the pistil of the same.

temperate, and tropical regions. *Illustrative Genera*:—Lemna, *Linn.*; Pistia, *Linn.* There are above 20 species. Their properties are unimportant.

Series 6.—*Apocarpæ.*

Order 30. TRIURIDACEÆ, the Triuris Order.—*Diagnosis.*—This is a small order of plants allied to Naiadaceæ, but usually to be distinguished by its rudimentary embryo. The flowers are also sometimes perfect.

Distribution, Numbers, and Properties.—Exclusively found in warm and tropical regions. *Illustrative Genera*:—Triuris, *Miers*; Sciaphila, *Blume.* There are 8 species. Their properties and uses are unknown.

Order 31. ALISMACEÆ, the Alisma Order.—Character.—Swamp or floating plants. *Leaves* narrow or with an expanded

lamina, parallel-veined. *Flowers* hermaphrodite or very rarely unisexual. *Perianth* inferior, arranged in two whorls, each consisting of three parts; the outer whorl herbaceous, the inner coloured. *Stamens* few or numerous; *anthers* introrse. *Carpels* distinct, several; *ovaries* superior, 1-celled; *ovules* solitary or 2 superposed; *placentas* axile or basal. *Fruit* dry. *Seeds* without albumen; *embryo* undivided, curved.

Distribution and Numbers.—These plants are principally found in the northern parts of the world. *Illustrative Genera*:—Alisma, *Juss.*; Actinocarpus, *R. Br.* There are about 50 species.

Properties and Uses.—Of little importance. Many have fleshy or mealy rhizomes, which are edible when cooked. Others

Fig. 976.

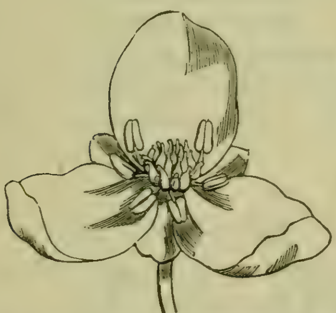


Fig. 977.

Fig. 976. Flower of a species of *Alisma*, with an inferior perianth arranged in two whorls each consisting of three parts, six stamens, and numerous separate carpels.——*Fig.* 977. Vertical section of the same flower.

possess astringent properties. *Alisma Plantago* had formerly a reputation as a remedy in hydrophobia.

Order 32. BUTOMACEÆ, the Butomus Order.—Character.—Aquatic plants with parallel-veined leaves, sometimes milky. *Flowers* hermaphrodite, showy. *Perianth* inferior, of six pieces, arranged in two whorls (*fig.* 978), the inner being coloured. *Stamens* few, or numerous. Carpels 3—6, or more, more or less distinct; *ovaries* superior; *ovules* numerous, arranged all over the inner surface of the ovaries. *Fruit* many-seeded, separating more or less when ripe into as many parts as there are component carpels. *Seeds* without albumen. *This order is included by Bentham and Hooker in Alismaceæ.*

Distribution and Numbers.—A few plants of this order occur in tropical countries, but the greater number inhabit the

northern parts of the world. *Illustrative Genera*:—Butomus, *Tourn.*; Limnocharis, *H. et B.* There are 7 species.

Properties and Uses.—Of little importance. *Butomus umbellatus*, the Flowering Rush, possesses acrid and bitter properties, and was at one time used in medicine. The roasted rhizomes are edible.

FIG. 978.

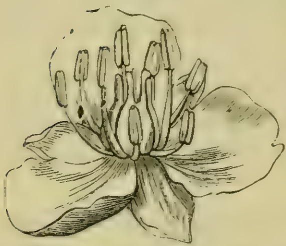


FIG. 979.

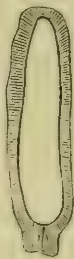


Fig. 978. A flower of the Flowering Rush (*Butomus umbellatus*), with an inferior perianth arranged in two whorls, nine stamens, and six carpels.——*Fig.* 979. Vertical section of the seed of the same.

Order 33. NAIADACEÆ, the Pondweed Order.—Character.—Aquatic plants with jointed cellular stems. *Leaves* with interpetiolar membranous stipules. *Flowers* small, unisexual (*figs.* 980 and 981), monœcious or diœcious, solitary or in spikes. *Perianth* either wanting, or present and composed of 2 or 4 parts, which are then free and scale-like. *Stamens* 1 or few, hypogynous; *pollen* globose or tubular.

FIG. 980.

FIG. 981.

FIG. 982.

FIG. 983.

Fig. 980. Two flowers of the Horned Pondweed (*Zannichellia palustris*), one staminate, the other pistillate.——*Fig.* 981. The gynœcium of the same, composed of four perfect carpels, and one imperfect.——*Fig.* 982. Vertical section of one of the carpels.——*Fig.* 983. Vertical section of the fruit and seed. All magnified. After Lindley.

Carpels 1 or more, distinct, with superior *ovaries* (*fig.* 981); *ovule* solitary (*fig.* 982). *Fruit* 1-celled, 1-seeded (*fig.* 983). *Seed* exalbuminous; *embryo* with a lateral cleft.

Distribution.—They are widely distributed, but are chiefly found in extra-tropical regions. *Illustrative Genera* :—Naias, *Willd.*; Zannichellia, *Michel*; Zostera, *Linn.*

Properties and Uses.—Their properties are of little importance.

Order 34. JUNCAGINACEÆ, the Arrow-grass Order.—Character.—*Herbs*, growing in marshes. *Leaves* with parallel veins. *Flowers* hermaphrodite, whitish or greenish. *Perianth* small, more or less scaly, inferior, in two whorls, each containing three pieces. *Stamens* 6, perigynous, *anthers* usually extrorse. *Carpels* 3—6, separate or more or less united; *ovules* 1—2. *Fruit* dry, ultimately separating into as many parts as there are carpels. *Seeds* attached to axile or basal placentas, exalbuminous; *embryo* straight, with a lateral cleft. *This order is included by Bentham and Hooker in Naiadaceæ.*

Distribution and Numbers.—The plants of this order are found more or less in nearly all parts of the world, but are most abundant in temperate and cold regions. *Illustrative Genera* :—Triglochin, *Linn.*; Potamogeton, *Linn.* There are about 50 species.

Properties and Uses.—Of little importance.

Series 7.—*Glumaceæ.*

Order 35. ERIOCAULACEÆ, the Eriocaulon or Pipewort Order. Character.—Aquatic or marsh plants. *Leaves* clustered, linear, usually grass-like. *Flowers* minute, unisexual, in dense heads, each flower arising from the axil of a membranous bract. *Perianth* membranous, tubular, 2—3-toothed or -lobed. *Stamens* 2—6; *anthers* 2-celled, introrse. *Ovary* superior, 2—3-celled. *Fruit* dehiscent, 2—3-celled, 2—3-seeded. *Seeds* pendulous, albuminous, hairy or winged; *embryo* lenticular, at the end of the albumen remote from the hilum.

Distribution, Numbers, and Properties.—Mostly natives of tropical America and the North of Australia. One species is found in Britain, *Eriocaulon septangulare*, With. The order contains about 200 species. Their properties are unimportant.

Order 36. DESVAUXIACEÆ, the Bristlewort Order.—Character.—Small sedge-like *herbs*, with setaceous sheathing *leaves*. *Flowers* glumaceous, enclosed in a terminal spathe. *Glumes* 1 or 2. *Paleæ* none, or 1 or 2 scales parallel with the glumes. *Stamens* 1 or very rarely 2; *anthers* 1-celled. *Carpels* 1—18, distinct or partially united, with 1 stigma and 1 pendulous ovule

in each ovary. *Fruit* composed of as many utricles as there are carpels. *Seeds* albuminous; *embryo* lenticular, terminal.

Distribution, Numbers, and Properties.—Natives of Australia and the South Sea Islands. *Illustrative Genera:*—Desvauxia, *R. Br.*; Aphelia, *R. Br.* There are about 15 species. Their properties and uses are unknown.

Order 37. RESTIACEÆ, the Restio Order.—Character.—*Herbs* or *undershrubs*. *Leaves* simple and narrow, or entirely absent. *Stems* stiff, either naked, or more commonly with slit convolute leaf-sheaths. *Flowers* with glumaceous *bracts*, spiked or aggregated, generally unisexual. No true *perianth*, its place

FIG 984.

FIG. 985.

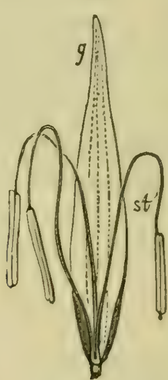


FIG. 986.

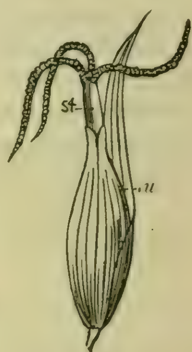


Fig. 984. A portion of the angular stem of a species of *Carex*, with a closed sheath.——*Fig.* 985. Staminate flower of a species of *Carex*. *st.* Stamens, with long filaments and pendulous innate anthers. *g.* Glume.——*Fig.* 986. Pistillate flower of a species of *Carex*, consisting of a glume at the base, and a pistil surrounded by an urn-shaped tube (*perigynium*), *u.* *st.* Style, terminated by three stigmas.

being usually supplied by 2—6 *glumes*. *Stamens* 2—3, adherent to the inner glumes, or the latter are sometimes absent; *anthers* generally 1-celled. *Ovary* 1—3-celled, with 1 pendulous ovule in each cell. *Fruit* capsular or nut-like. *Seed* solitary, pendulous, albuminous; *embryo* lenticular, terminal.

Distribution and Numbers.—Natives principally of South Africa, South America, and Australia. Some are also found in the tropical parts of Asia; but none occur in Europe. *Illustrative Genera:*—Leptocarpus, *R. Br.*; Restio, *Linn.* There are about 180 species.

Properties and Uses.—Unimportant. The wiry stems of

some species have been used for basket-making, &c., and for thatching.

Order 38. CYPERACEÆ, the Sedge Order.—Character.—Grass-like or rush-like, usually perennial *herbs*. *Stems* solid, without joints or partitions, frequently angular. *Leaves* without ligules, and with entire or closed sheaths round the stem. *Flowers* spiked, imbricate, hermaphrodite or unisexual, each arising from the axil of 1—3 bracts or glumes. (*The lowermost glumes are frequently empty, that is, without flowers in their axils.*) *Perianth* absent, or existing in the female flowers in the form of a tube (*perigynium*), or as hypogynous scales or bristles.

FIG. 987.

FIG. 988.

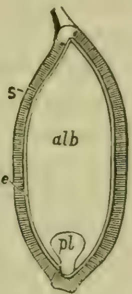


FIG. 989.

Fig. 987. Hermaphrodite flower of a species of Club-rush (*Scirpus*), the glume having been removed. *b.* Hypogynous setæ or bristles forming a kind of perianth. *st.* Hypogynous stamens with 2-celled innate anthers. *o.* Ovary. *s.* Style. *stig.* Stigmas.——*Fig.* 988. Vertical section of the fruit of a species of *Carex*. *s.* Pericarp. *te.* Integuments of the seed. *alb.* Albumen. *pl.* Embryo.——*Fig.* 989. Embryo of a species of *Carex* removed from the albumen. *a.* Lateral swelling. *r.* Radicle. *c.* Cotyledon. *f.* Slit corresponding to the plumule.

Stamens hypogynous, 1—12, commonly 3; *anthers* 2-celled, innate. *Ovary* 1-celled, superior, with 1 erect anatropous ovule. *Fruit* indehiscent, 1-seeded. *Seed* with fleshy or mealy albumen; *embryo* lenticular, enclosed in the base of the albumen.

Diagnosis.—Grass-like or rush-like herbs with solid and usually angular stems. Leaves without ligules and with entire sheaths. Stamens few, hypogynous; anthers innate, 2-celled. Ovary superior, 1-celled; ovule solitary, erect, anatropous. Fruit indehiscent, 1-celled, 1-seeded. Embryo enclosed in the base of the albumen.

Distribution and Numbers.—Natives of all parts of the

world, and found especially in marshes, ditches, and about running streams. *Illustrative Genera :*—Carex, *Linn.*; Cyperus, *Linn.*; Scirpus, *Linn.* There are about 2,000 species.

Properties and Uses.—Although closely allied in their botanical characters to the Graminaceæ, the Cyperaceæ are altogether deficient in the nutritive and other qualities which render the plants of the Graminaceæ so eminently serviceable to man and other animals. Indeed the order generally is remarkable for the absence of any important properties. Some of the plants are slightly aromatic, stomachic, and diaphoretic, others demulcent and alterative, and a few have been used for economic purposes. The underground stems of certain species are edible when roasted or boiled. Some of the species by spreading and interlacing their subterranean stems through the sand of the sea-shore, and thus binding it together, prevent it from being washed away by the receding waves, and in this way protect the neighbouring coast from encroachments of the sea. (See also *Properties and Uses of the Graminaceæ.*)

FIG. 990.

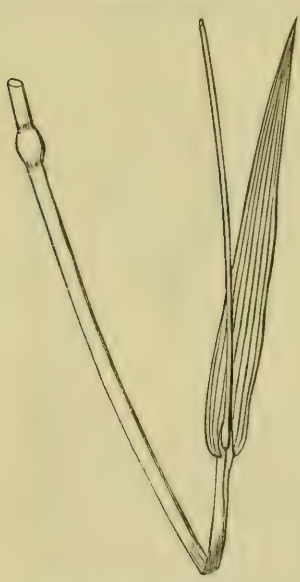


Fig. 990. A portion of the stem of the Cat's-tail Grass (*Phleum pratense*), bearing a leaf with parallel veins, and a split sheath.

Order 39. GRAMINACEÆ, the Grass Order.-Character.-*Herbs*, *shrubs*, or *arborescent plants*, with round, commonly hollow, jointed stems. *Leaves* alternate, with parallel veins and split sheaths, and with a ligule at the base of the lamina. *Flowers* hermaphrodite or unisexual, arranged in spiked, panicled, or racemose locustæ; or solitary. *No true perianth*, its place being supplied by imbricate bracts, of which there are commonly 2, called *glumes*, or rarely 1 (*fig.* 992); these glumes are placed at the base of the solitary flower, or at the base of each locusta. *Occasionally the glumes are altogether absent.* Each flower is also usually furnished with two other alternate bracts (*paleæ*) (or sometimes the inner palea, *pi*, is wanting), the outer palea is frequently termed the *flowering glume*; and 2 or 3

hypogynous scales (*lodiculæ*, *squamulæ*, or *glumellules*); these scales also are occasionally absent. *Stamens* 1—6, usually 3 *filaments* capillary; *anthers* 2-celled, versatile. *Ovary* superior 1-celled, with a solitary ascending ovule; *stigmas* feathery or

FIG. 991.

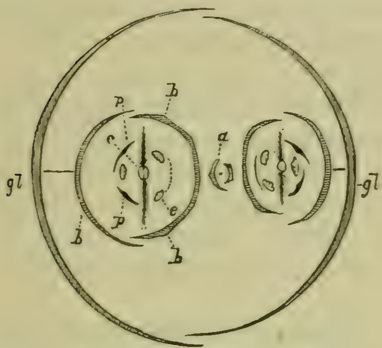


FIG. 992.

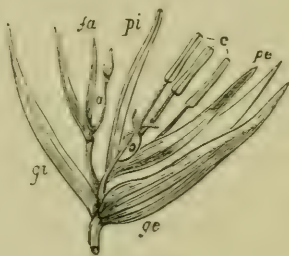


FIG. 993.

FIG. 994.

FIG. 995.

FIG 996.

Fig. 991. Diagram of a spikelet of the Oat (*Avena*). (From Le Maout.) *gl*, *gl*. Two glumes, enclosing two hermaphrodite flowers, and one, *a*, abortive. *b*. The outer palea or flowering glume. *b*, *b*. The inner palea. *p*, *p*. Two scales (*squamulæ* or *glumellules*); the dotted curved line on the right marks the position of a third abortive scale. *e*. Stamens. *c*. Ovary.——*Fig.* 992. A spikelet (locusta) of the Oat (*Avena sativa*). *ge*. Outer glume. *gi*. Inner glume. *pe*. Outer palea or flowering glume of the fertile flower. *pi*. Inner palea of the same. *e*. Stamens. *o*. Ovary. *fa*, and *a*. Abortive flowers.——*Fig.* 993. Fertile flower of the Oat, without the paleæ. *p*. Lodicules. *e*. Stamens. *o*. Ovary. *s*, *s*. Feathery stigmas.——*Fig.* 994. One of the florets of a species of Meadow Grass (*Poa pratensis*).——*Fig.* 995. One of the florets of the Hard Fescue Grass (*Festuca duriuscula*).——*Fig.* 996. The embryo of the Oat. *a*. Lateral swelling. *c*. Cotyledon. *r*. Radicle. *f*. Slit corresponding to the plumule.

hairy. *Fruit* a caryopsis. *Seed* with mealy albumen; *embryo* lenticular, lying on one side of the base of the albumen.

According to the views of some botanists, the paleæ represent

a calyx and correspond to the outer whorl of the perianth in Liliaceæ. This is supported by the fact that the upper pale is two-pointed as if composed of two leaves laterally united. In a species of Bromus it is cleft to the base, so that there are three paleæ in the whorl. The lodicules are held to represent the corolla.

Other writers regard the lodicules as the only representatives of the perianth, and consider the paleæ to be bracts.

Diagnosis.—Leaves alternate, with split sheaths, and a ligule at the base of the lamina. Flowers generally arranged in spikelets or locustæ, or rarely solitary. Flowers glumaceous; paleæ usually 2 in each flower. Stamens hypogynous, few, usually 3, with capillary filaments, and versatile anthers. Ovary superior, with a solitary ascending ovule; stigmas feathery or hairy. Fruit a caryopsis. Seed with mealy albumen, with the embryo on one side at the base.

Distribution and Numbers.—Grasses are universally distributed over the globe. In temperate and cold climates they are herbaceous and of moderate height, while in tropical countries they become shrubby and arborescent, and sometimes grow to the height of 50 or 60 feet. Grasses usually grow together in large masses, and thus form the verdure of great tracts of soil, and hence have been termed social plants. *Illustrative Genera:*—Panicum, *Linn.*; Anthoxanthum, *Linn.*; Phleum, *Linn.*; Agrostis, *Linn.*; Dactylis, *Linn.*; Bromus, *Linn.* There are over 4,000 species.

Properties and Uses.—Of all the orders in the Vegetable Kingdom this is the most important to man, as it affords the various fruits, commonly known as Cereal Grains, which supply the principal material of his daily bread in most countries of the world; besides being eminently serviceable in other respects, by supplying fodder for cattle, and yielding sugar and other very useful products. It is a remarkable fact that the native countries of our more important Cereals or Corn-producing plants are altogether unknown. A few of the Grasses yield fragrant volatile oils. Paper has long been made from the bamboo in India, China, and some other parts of the world; and straw is now largely employed for a like purpose in this country and elsewhere. Other Grasses have also, within the last few years, been used to a great extent for making paper. Almost all Grasses are wholesome, but one or more species of *Bromus* have been erroneously reputed to be purgative, and one, *Lolium temulentum*, is said to be narcotic and

poisonous. Some of the species serve to bind together the sand on the seashore, and thus prevent the encroachment of the sea on the neighbouring coast. (See also *Properties and Uses of the Cyperaceæ*.)

Artificial Analysis of the Orders in the Class.

MONOCOTYLEDONES.

(*Modified from Lindley.*)

Sub-Class I.—PETALOIDEÆ.

1. FLOWERS WITH AN EVIDENT PERIANTH.

A. Ovary inferior (*Inferæ* or *Epigynæ*).

a. *Flowers gynandrous.*	
Ovary 1-celled. Placentas parietal . . .	*Orchidaceæ.*
Ovary 3-celled. Placentas axile	*Apostasiaceæ.*
b. *Flowers not gynandrous.*	
1. Veins of leaves diverging from the midrib, and parallel to each other.	
Embryo enclosed in endosperm.	
Anther 2-celled. Filament one, not petaloid	*Zingiberaceæ.*
Embryo not enclosed in endosperm.	
Anther 1-celled. Filament one . . .	*Marantaceæ.*
Anther 2-celled. Filaments more than one	*Musaceæ.*
2. Veins of leaves diverging from the base, and parallel to the midrib.	
Stamens 3.	
Anthers extrorse	*Iridaceæ.*
Anthers introrse	*Burmanniaceæ.*
Stamens 6.	
Anthers extrorse	*Burmanniaceæ.*
Anthers introrse.	
Leaves equitant	*Hæmodoraceæ.*
Leaves flat.	
Fruit 1-celled	*Taccaceæ.*
Fruit 3-celled.	
Outer whorl of the perianth petaloid	*Amaryllidaceæ.*
Outer whorl of the perianth not petaloid	*Bromeliaceæ.*
Stamens more than 6	*Hydrocharidaceæ.*

3. Veins of leaves reticulated.
Flowers unisexual . . . . . *Dioscoreaceæ.*

B. Ovary superior (*Superæ*). Leaves parallel-veined.

a. *Outer whorl of the perianth herbaceous or glumaceous.*

Carpels more or less distinct.
Seeds attached over the whole inner walls of the fruit . . . . *Butomaceæ.*
Seeds attached to axile or basal placentas.
Flowers conspicuous. Embryo curved, without a slit . . . . . *Alismaceæ.*
Flowers inconspicuous. Embryo straight, with a lateral slit . . . . *Juncaginaceæ.*
Carpels combined.
Inner whorl of the perianth different from the outer.
Placentas axile. Anthers 2-celled. Capsule 2—3-celled . . . . . *Commelynaceæ.*
Placentas parietal.
Anthers 2-celled. Capsule 1-celled . *Xyridaceæ.*
Anthers 1-celled. Capsule 1-celled . *Mayaceæ.*
The outer and inner whorls of the perianth alike.
Flowers on a spadix. Embryo with a lateral slit . . . . . . *Aroidaceæ.*
Flowers not on a spadix. Embryo without a slit . . . . . . *Juncaceæ.*

b. *Outer whorl of the perianth petaloid, or the whole petaloid when only one whorl is present.*

Carpels more or less distinct.
Seeds solitary. Flowers on a spadix . . *Palmaceæ.*
Seeds numerous. Flowers not on a spadix.
Anthers extrorse . . . . . *Colchicaceæ.*
Anthers introrse.
Perianth of 6 parts. Seeds without albumen . . . . . . *Butomaceæ.*
Perianth of 2 parts. Seeds with albumen *Philydraceæ.*
Carpels combined.
Flowers on a spadix . . . . *Palmaceæ.*
Flowers not on a spadix.
Perianth rolled inwards after flowering. Aquatics . . . . . *Pontederiaceæ.*
Perianth not rolled inwards after flowering, conspicuous . . . . *Liliaceæ.*

C. Ovary superior. Leaves net-veined.

a. *Placentas basal* . . . . *Roxburghiaceæ.*
b. *Placentas axile* . . . . . . *Smilaceæ.*
c. *Placentas parietal* . . . . . . *Philesiaceæ.*

2. Flowers either naked, or with a whorled scaly Perianth, generally unisexual.

A. Flowers on a spadix.

a. *Flowers bisexual.*
Embryo cleft . . . . *Aroidaceæ.*
Embryo solid . . . . *Pandanaceæ.*

b. *Flowers unisexual.*
Embryo solid . . . . *Pandanaceæ.*
Embryo cleft on one side.
Flowers with a true spathe. Fruit succulent.
Anthers sessile, or nearly so . . . *Aroidaceæ.*
Flowers without a true spathe. Fruit dry.
Anthers on long filaments . . . *Typhaceæ.*

B. Flowers not arranged on an evident spadix.

a. *Flowers bisexual.*
Ovary superior . . . . *Juncaginaceæ.*
Ovary inferior . . . . *Hydrocharidaceæ.*

b. *Flowers unisexual.*
Ovules erect.
Embryo perfect.
Seed without albumen . . . . *Naiadaceæ.*
Seed with albumen . . . . . *Pistiaceæ.*
Embryo rudimentary . . . . . *Triuridaceæ.*
Ovules pendulous.
Carpel solitary.
Seed without albumen.
Pollen globose or tubular . . . *Naiadaceæ.*
Seed with albumen . . . . . *Restiaceæ.*
Carpels several, distinct.
Anthers 2-celled . . . . . . *Naiadaceæ.*
Anthers 1-celled . . . . . . *Desvauxiaceæ.*
Carpels several, combined.
Anthers 1-celled.
Stamens 2—3 . . . . . . *Restiaceæ.*
Stamen 1 . . . . *Desvauxiaceæ.*
Anthers 2-celled. Placentas axile.
Seeds with rows of hairs . . . *Eriocaulaceæ*
Seeds without rows of hairs . . . *Restiaceæ.*
Anthers 2-celled. Placentas parietal . *Xyridaceæ.*

Sub-Class II.—Glumaceæ.

Stem solid. Leaf-sheaths not slit. Embryo basilar, within the albumen	*Cyperaceæ.*
Stem hollow. Leaf-sheaths slit. Embryo basilar, outside the albumen	*Graminaceæ.*

Synopsis of the British Natural Orders of Class X.

Monocotyledones.

A. Leaves net-veined.

1. Floral envelopes whorled.

Perianth inferior. Flowers perfect .	*Liliaceæ* (*Trilliaceæ*).
Perianth superior. Flowers diœcious .	*Dioscoreaceæ.*

2. Perianth absent. Flowers on a spadix (monœcious)	*Aroidaceæ* (*Aroideæ*).

B. Leaves parallel-veined, persistent.

1. Floral envelopes whorled or absent.

a. Ovaries more than one, with styles or stigmas distinct.

Perianth 4-parted or 0, or inconspicuous	*Naiadaceæ* (*Potamogetoneæ*).
Perianth 6-parted.	
Placentation diffuse	*Butomaceæ.*
Placentation axile or basal.	
Flowers conspicuous	*Alismaceæ.*
Flowers inconspicuous	*Juncaginaceæ.*

b. Ovary single.

Ovary inferior.	
Stamen 1. Flowers gynandrous . .	*Orchidaceæ.*
Stamens free from the style.	
Perianth petaloid.	
Stamens 3, anthers extrorse . .	*Iridaceæ.*
Stamens 6, anthers introrse . .	*Amaryllidaceæ.*
Three outer segments of perianth herbaceous	*Hydrocharidaceæ.*
Ovary superior.	
Perianth hexapetaloid. Flowers perfect.	
Perianth conspicuous	*Liliaceæ.*
Perianth scale-like	*Aroidaceæ* (*Acoreæ*).
Perianth more or less glumaceous, or partly coloured, or wanting.	
Flowers perfect. Perianth 6-parted, stamens 6	*Juncaceæ.*

Flowers monœcious.	
Flowers on a spadix.	
Spadix thick. Spathe absent .	*Typhaceæ.*
Spathe present	*Aroidaceæ* (*Aroideæ*).
Flowers not on a spadix.	
Flowers capitate. Stamens 2—5 .	*Eriocaulaceæ.*
Flowers 2 in a spathe, 1 ♂, 1 ♀ .	*Lemnaceæ.*
Flowers in two rows on one side of the spathe, enclosed by a fold of the leaf, or solitary	*Naiadaceæ.*
2. Floral envelopes imbricated, bract-like.	
Leaves with entire sheaths, stems solid .	*Cyperaceæ.*
Leaves with split sheaths, stems hollow .	*Graminaceæ.*

CLASS XI.—DICOTYLEDONES.

The plants comprised in this group are usually now divided into three sub-classes as under :—

Sub-Class I.—MONOCHLAMYDEÆ.

The flowers have never more than a single whorl of perianth leaves, which may be petaloid or sepaloid. Very frequently there is no perianth. The flowers are very frequently unisexual. Bentham and Hooker, in the 'Genera Plantarum,' divide them further into eight series, each comprising several Natural Orders as under :—

Series 1.—*Curvembryeæ.*

Characters.—Endosperm frequently farinaceous. Embryo curved, eccentric, lateral or peripheral, rarely straight. Ovules most frequently 1 in the ovary or 1 in each loculus. Flowers ☿, or in some genera unisexual or polygamous. Petals very rare; stamens equal in number to the segments of the perianth; rarely fewer or more.

Order 1. Nyctagineæ.
2. Amarantaceæ.
3. Chenopodiaceæ.
4. Basellaceæ.
5. Phytolaccaceæ.
6. Petiveriaceæ.
7. Batidaceæ.
8. Polygonaceæ.

Series 2.—*Multiovulatæ aquaticæ.*

Characters.—Aquatic herbs, submerged. Ovary syncarpous, ovules numerous in each loculus or on each placenta.

Order 9.—*Podostemaceæ.*

Series 3.—*Multiovulatæ terrestres.*

Characters.—Terrestrial trees or shrubs. Ovary syncarpous; ovules numerous in each loculus or on each placenta.

Order 10. Nepenthaceæ.
11. Cytinaceæ.
12. Rafflesiaceæ.
13. Aristolochiaceæ.

Series 4.—*Micrembryeæ.*

Characters.—Ovary syncarpous, monocarpous, or apocarpous. Ovules generally solitary in each carpel, rarely 2 or more. Endosperm copious, fleshy, or rarely farinaceous. Embryo very minute.

Order 14. Piperaceæ.
15. Saururaceæ.
16. Chloranthaceæ.
17. Myristicaceæ.
18. Monimiaceæ.
19. Atherospermaceæ.

Series 5.—*Daphnales.*

Characters.—Ovary monocarpous, very rarely syncarpous, with 2 to 4 loculi; ovules solitary or in pairs in the ovary or in each loculus. Trees or shrubs, very rarely herbs. Flowers generally ☿. Perianth perfect, sepaloid, 1—2-seriate. Stamens perigynous, equal in number to the lobes of the perianth or double the number: rarely fewer.

Order 20. Lauraceæ.
21. Proteaceæ.
22. Thymelaceæ.
23. Aquilariaceæ.
24. Penæaceæ.
25. Elæagnaceæ.

Series 6.—*Achlamydosporeæ.*

Characters.—Ovary unilocular with 1—3 ovules; ovules most frequently poorly developed before flowering. Seeds albuminous, but without a testa, either free in the pericarp or attached to its walls. Perianth generally perfect, sepaloid or petaloid.

Order 26. Loranthaceæ.
27. Santalaceæ.
28. Balanophoraceæ.

Series 7.—*Unisexuales.*

Characters.—Flowers unisexual; ovary syncarpous or monocarpous; ovules solitary or in pairs in the ovary or in each loculus. Endosperm copious, fleshy, scanty, or absent. Trees or shrubs, rarely herbs. Stipules generally present. Perianth sepaloid, or minute, or absent. Styles equal in number to the carpels; not infrequently lobed.

Order 29. Euphorbiaceæ.
30. Scepaceæ.
31. Stilaginaceæ.
32. Urticaceæ.
33. Moraceæ.
34. Cannabinaceæ.
35. Artocarpaceæ.
36. Ulmaceæ.
37. Platanaceæ.
38. Juglandaceæ.
39. Myricaceæ.
40. Casuarinaceæ.
41. Cupuliferæ.
42. Betalaceæ.

Series 8.—*Ordines anomali.*

Order 42. Salicaceæ.
43. Lacistemaceæ.
44. Empetraceæ.
45. Ceratophyllaceæ.

Sub-Class II.—Polypetalæ.

Flowers with both calyx and corolla, the latter usually consisting of free petals. Both stamens and pistil usually present.

Series 1.—Thalamifloræ.

The calyx generally consists of free sepals; the petals often more numerous than the sepals: stamens nearly always hypogynous, the pistil syncarpous or apocarpous.

Bentham and Hooker divide the Thalamifloræ into Cohorts as under:—

Cohort 1.—*Ranales.*

Characters.—Flowers generally acyclic or hemicyclic; perianth usually 2-seriate; stamens commonly ∞, gynœcium apocarpous, monocarpous, or rarely syncarpous.

Order 46. Ranunculaceæ.
47. Dilleniaceæ.
48. Calycanthaceæ.
49. Magnoliaceæ.
50. Anonaceæ.

Order 51. Menispermaceæ.
52. Berberidaceæ.
53. Nymphæaceæ.

Cohort 2.—*Parietales.*

Characters.—Flowers with calyx and corolla, sepals free, petals free, stamens definite or ∞, pistil syncarpous; ovary with parietal placentation.

Order 54. Sarraceniaceæ.
55. Papaveraceæ.
56. Fumariaceæ.
57. Cruciferæ.
58. Capparidaceæ.
59. Resedaceæ.
60. Cistaceæ.
61. Violaceæ.
62. Sauvagesiaceæ.
63. Canellaceæ.
64. Bixaceæ.

Cohort 3.—*Polygales.*

Characters.—Gynœcium syncarpous; ovary usually 2—3-celled; placentation generally axile, or very rarely parietal.

Order 65. Pittosporaceæ.
66. Tremandraceæ.
67. Polygalaceæ.
68. Vochysiaceæ.

Cohort 4.—*Caryophyllales.*

Characters.—Gynœcium syncarpous; ovary ultimately 1-celled, with free-central placentation, or very rarely parietal.

Order 69. Caryophyllaceæ.
70. Paronychiaceæ.
71. Portulacaceæ.
72. Tamaricaceæ.
73. Reaumuriaceæ.

Cohort 5.—*Guttiferales.*

Characters.—Gynœcium syncarpous; ovary 1—many-celled, placentation usually axile.

Order 74. Elatinaceæ.
75. Hypericaceæ.

Order 76. Guttiferæ or Clusiaceæ.
77. Ternstrœmiaceæ or Camelliaceæ.
78. Marcgraviaceæ.
79. Rhizobolaceæ.
80. Dipterocarpeæ or Dipteraceæ.
81. Chlenaceæ.

Cohort 6.—*Malvales.*

Characters.—Calyx with valvate æstivation. Stamens usually ∞. Placentation axile or sutural.

Order 82. Malvaceæ.
83. Sterculiaceæ.
84. Tiliaceæ.

Series 2.—Discifloræ.

The sepals are free or coherent, petals usually in a single whorl; the stamens are hypogynous or attached to a disc which is sometimes perigynous; the ovary is generally syncarpous.

According to Bentham and Hooker, the Discifloræ comprise the following Cohorts:—

Cohort 1.—*Geraniales.*

Characters.—Flowers with their parts arranged in fives; frequently two whorls of stamens which are then obdiplostemonous; disc often conspicuous, but sometimes absent. Stamens hypogynous, pistil syncarpous.

Order 85. Linaceæ.
86. Humiriaceæ.
87. Malpighiaceæ.
88. Zygophyllaceæ.
89. Geraniaceæ.
90. Balsaminaceæ.
91. Vivianiaceæ.
92. Tropæolaceæ.
93. Limnanthaceæ.
94. Oxalidaceæ.
95. Rutaceæ.
96. Simarubaceæ.
97. Ochreaceæ.
98. Burseraceæ.
99. Meliaceæ.
100. Cedrelaceæ.
101. Chailletiaceæ.

Cohort 2.—*Olacales.*

Characters.—Calyx imbricate. Gynœcium syncarpous, ovules suspended, raphe dorsal. Seeds albuminous.

Order 102. Olaccaceæ.
103. Icacinaceæ.
104. Cyrillaceæ.
105. Phytocrenaceæ.
106. Aquifoliaceæ or Ilicaceæ.

Cohort 3.—*Celastrales.*

Characters.—Calyx imbricate or valvate. Gynœcium syncarpous; ovules erect, raphe ventral. Seeds usually albuminous, radicle inferior. Nearly always trees or shrubs.

Order 107. Celastraceæ.
108. Hippocrateaceæ.
109. Stackhousiaceæ.
110. Rhamnaceæ.
111. Vitaceæ.

Cohort 4.—*Sapindales.*

Characters.—Calyx imbricate; gynœcium usually syncarpous or rarely apocarpous; ovules generally ascending with raphe ventral. Seeds usually exalbuminous. Trees or shrubs, rarely herbs.

Order 112. Sapindaceæ.
113. Aceraceæ.
114. Staphyleaceæ.
115. Sabiaceæ.
116. Anacardiaceæ.

Anomalous Orders.

Order 117. Coriariaceæ.
118. Moringaceæ.

Series 3.—Calycifloræ.

The calyx is usually gamosepalous, stamens perigynous or epigynous; gynœcium apocarpous or syncarpous. Bentham and Hooker divide this group into the following Cohorts :—

Cohort 1.—*Rosales.*

Characters.—Stamens perigynous or epigynous. Gynœcium usually simple or apocarpous; rarely syncarpous. Ovary

superior or inferior; placentation usually marginal or axile; styles generally solitary or distinct; rarely united, seeds albuminous or exalbuminous.

Order 119. Connaraceæ.
120. Leguminosæ.
121. Rosaceæ.
122. Saxifragaceæ.
123. Francoaceæ.
124. Escalloniaceæ.
125. Philadelphaceæ.
126. Hydrangeaceæ.
127. Hensloviaceæ.
128. Cunoniaceæ.
129. Ribesiaceæ.
130. Crassulaceæ.
131. Droseraceæ.
132. Hamamelidaceæ.
133. Bruniaceæ.
134. Haloragaceæ.
135. Callitrichaceæ.

Cohort 2.—*Myrtales.*

Characters.—Gynœcium syncarpous; style usually undivided; ovary inferior, or included within the calyx tube; placentation generally axile. Seeds exalbuminous. Leaves nearly always simple.

Order 136. Rhizophoraceæ.
137. Combretaceæ.
138. Myrtaceæ.
139. Lecythidaceæ.
140. Barringtoniaceæ.
141. Chamælauciaceæ.
142. Belvisiaceæ.
143. Melastomaceæ.
144. Lythraceæ.
145. Onagraceæ.

Cohort 3.—*Passiflorales.*

Characters.—Gynœcium syncarpous; ovary usually 1-celled or sometimes spuriously 3-celled; placentation parietal; ovules numerous. Seeds albuminous or exalbuminous. Leaves simple.

Order 146. Samydaceæ.
147. Homaliaceæ.
148. Loasaceæ.
149. Turneraceæ.
150. Passifloraceæ.
151. Malesherbiaceæ.
152. Papayaceæ.
153. Cucurbitaceæ.
154. Begoniaceæ.
155. Datiscaceæ.

Cohort 4.—*Ficoidales.*

Characters.—Stamens generally numerous, epigynous or perigynous. Leaves simple when present; exstipulate. Stem usually fleshy.

Order 156. Cactaceæ.
157. Mesembryanthaceæ or Ficoidaceæ.

Cohort 5.—*Umbellales.*

Characters.—Stamens few, epigynous. Gynœcium syncarpous, ovary inferior, ovules solitary, pendulous; styles surrounded at the base by an epigynous disc. Seeds albuminous. Leaves exstipulate.

Order 158. Umbelliferæ.
159. Araliaceæ.
160. Cornaceæ.
161. Garryaceæ.
162. Alangiaceæ.

Sub-Class III.—Gamopetalæ or Corollifloræ.

The petals are coherent and the stamens are in nearly all cases attached to the tube of the corolla. Ovary usually syncarpous. This sub-class is divided by Bentham and Hooker into 3 series, each comprising Cohorts and Natural Orders as under:—

Series 1.—Inferæ or Epigynæ.

Ovary Inferior.

Cohort 1.—*Rubiales.*

Characters.—Stamens epipetalous and alternate with the lobes of the corolla. Ovary 1- or more-celled, but usually 2-celled. Cells of the ovary with 1—many ovules. Seeds albuminous. Leaves generally opposite.

Order 163. Caprifoliaceæ.
164. Rubiaceæ.

Cohort 2.—*Asterales.*

Characters.—Stamens epipetalous and alternate with the lobes of the corolla when equal to them in number. Ovary 1-celled, ovule solitary. Fruit dry and indehiscent. Seeds usually exalbuminous. Leaves exstipulate.

Order 165. Valerianaceæ.
166. Dipsaceæ.
167. Calyceraceæ.
168. Compositæ.

Cohort 3.—*Campanales.*

Characters.—Stamens epigynous, usually free from the corolla. Ovary generally 2—6-celled, with numerous ovules in each cell. Fruit capsular. Seeds albuminous. Mostly herbs, rarely shrubs. Leaves usually alternate, exstipulate.

Order 169. Stylidiaceæ.
170. Goodeniaceæ.
171. Campanulaceæ.
172. Lobeliaceæ.

Series 2.—Superæ or Heteromeræ.

Ovary superior except in Vacciniaceæ; stamens epipetalous, but sometimes attached so near the base of the petals as to appear almost or quite free and hypogynous.

Cohort 1.—*Ericales.*

Characters.—Stamens generally hypogynous, except in Vacciniaceæ, and twice the number of the lobes of the corolla; or equal in number and then alternate with the lobes. Ovary usually with more than 2 cells; placentation generally axile; style undivided.

Order 173. Vacciniaceæ.
174. Ericaceæ.
175. Monotropaceæ.
176. Epacridaceæ.
177. Diapensiaceæ.
178. Stilbaceæ.

Cohort 2.—*Primulales.*

Characters.—Stamens generally epipetalous, equal in number to the lobes of the corolla and opposite to them. Ovary

1-celled, with free-central placenta and numerous ovules, or with a solitary ovule suspended from a long funiculus arising from the centre of the cell at the base.

Order 179. Plumbaginaceæ.
180. Primulaceæ.
181. Myrsinaceæ.

Cohort 3.—*Ebenales.*

Characters.—Stamens epipetalous, equal in number to and opposite the lobes of the corolla or separate petals; or more numerous. Ovary more than 1-celled, placentation axile. Fruit fleshy, seeds 1 or few, large. Trees or shrubs; leaves alternate.

Order 182. Sapotaceæ.
183. Ebenaceæ.
184. Styraceæ.

Series 3.—Bicarpellatæ.

Ovary superior, usually of two carpels. Stamens epipetalous.

Cohort 1.—*Gentianales.*

Characters.—Corolla regular, stamens generally epipetalous, equal in number to and alternate with the lobes of the corolla; rarely fewer. Leaves usually opposite and entire; rarely compound; very rarely alternate.

Order 185. Oleaceæ.
186. Salvadoraceæ.
187. Apocynaceæ.
188. Asclepiadaceæ.
189. Loganiaceæ.
190. Gentianaceæ.

Cohort 2.—*Polemoniales.*

Characters.—Corolla regular or nearly so. Stamens epipetalous, equal in number to and alternate with the corolla lobes. Leaves alternate or rarely opposite; usually simple and entire; or sometimes lobed and rarely compound; always ex-stipulate.

Order 191. Polemoniaceæ.
192. Hydrophyllaceæ.
193. Boraginaceæ.
194. Ehretiaceæ.
195. Cordiaceæ.

Order 196. Convolvulaceæ.
197. Nolanaceæ.
198. Solanaceæ.

Cohort 3.—*Personales.*

Characters.—Flowers generally heteromerous. Corolla usually irregular. Stamens epipetalous; posterior one often suppressed or appearing as a staminode; generally four and didynamous; sometimes five or two. Ovules generally numerous or two superposed.

Order 199. Scrophulariaceæ.
200. Orobanchaceæ.
201. Lentibulariaceæ.
202. Columelliaceæ.
203. Gesneraceæ.
204. Bignoniaceæ.
205. Crescentiaceæ.
206. Pedaliaceæ.
207. Acanthaceæ.

Cohort 4.—*Lamiales.*

Characters.—Flowers generally heteromerous. Corolla usually irregular. Stamens epipetalous, posterior one commonly suppressed; usually four and didynamous, or rarely two. Carpels or cells each with one ovule or two collateral ones. No stipules.

Order 208. Selaginaceæ.
209. Verbenaceæ.
210. Myoporaceæ.
211. Labiatæ.

Anomalous Order.

Order 212.—Plantaginaceæ.

Sub-Class I.—Monochlamydeæ, or Incompletæ.

Series 1.—*Curvembryeæ.*

Order 1. Nyctaginaceæ, the Marvel of Peru Order.—Character.—*Herbs*, *shrubs*, or *trees*, with the stems usually tumid at the joints. *Leaves* generally opposite and entire. *Flowers* with an involucre. *Calyx* tubular or funnel-shaped, often coloured, plaited in æstivation, contracted towards the middle, its base persistent and ultimately becoming indurated and forming a spurious pericarp. *Stamens* 1 or many, hypogynous. *Ovary* superior, 1-celled; *ovule* solitary; *style* 1; *stigma* 1. *Fruit* a utricle, enclosed by the hardened persistent base of the calyx. *Seed* solitary; *embryo* coiled round mealy albumen, with foliaceous cotyledons, and an inferior radicle.

Distribution and Numbers.—Natives exclusively of warm regions. *Illustrative Genera* :—Mirabilis, *Linn.* ; Pisonia, *Plum.* There are about 100 species.

Properties and Uses.—Chiefly remarkable for the presence of a purgative property in their roots; which is especially the case with those of *Mirabilis Jalapa* and *M. longiflora*. *M. dichotoma*, Marvel of Peru, is commonly known by the name of the Four-o'clock Plant, from opening its flowers in the afternoon. *Boerhaavia diffusa* is said to possess expectorant properties.

Order 2. Amarantaceæ, the Amaranth Order.—Character.—*Herbs* or *shrubs*. *Leaves* simple, exstipulate, opposite or alternate. *Flowers* crowded, spiked or capitate, bracteated, hermaphrodite, or occasionally unisexual. *Calyx* of 3—5 sepals, dry and scarious, inferior, persistent, often coloured, imbricate. *Stamens* 5, hypogynous and opposite to the sepals, or a multiple of that number; *anthers* 2- or 1-celled. *Ovary* free, 1-celled, with 1 or more ovules; *style* 1 or none; *stigma* simple or compound. *Fruit* a utricle or caryopsis, or sometimes baccate. *Seeds* 1 or more, pendulous; *embryo* curved round mealy albumen; *radicle* next the hilum.

Distribution and Numbers.—The plants of this order are most abundant in tropical regions, and are altogether unknown in the coldest climates. *Illustrative Genera* :—Celosia, *Linn.*; Amarantus, *Linn.* There are nearly 500 species.

Properties and Uses.—Unimportant. *Amarantus spinosus* and other Indian species possess mucilaginous properties.

Another Indian species, *Achyranthes aspera*, is also reputed to be astringent and diuretic. *Gomphrena officinalis* and *G. macrocephala* are used in Brazil in intermittent fevers, diarrhœa, and some other diseases. Some of the species have bright-coloured persistent flowers, and are hence cultivated in our gardens, as *Amarantus caudatus*, Love-lies-bleeding; *Amarantus hypochondriacus*, Prince's-feathers; *Celosia cristata*, Cockscomb; and others.

Order 3.—CHENOPODIACEÆ, the Goosefoot Order.—Character.—*Herbs* or *undershrubs*, more or less succulent. *Leaves* exstipulate, usually alternate, rarely opposite. *Flowers* minute, greenish, usually ebracteate, hermaphrodite or unisexual. *Calyx* persistent, usually divided nearly to the base, imbricate. *Stamens* equal in number to the lobes of the calyx and opposite to them, or rarely fewer, hypogynous or inserted into the base of the lobes; *anthers* 2-celled. *Ovary* superior or partly inferior, 1-celled, with a single ovule attached to its base; *style* usually in 2—4 divisions, rarely simple. *Fruit* usually an achænium or utricle, or sometimes baccate. *Seed* solitary; *embryo* coiled into a ring or spiral, with or without albumen; *radicle* towards the hilum.

Diagnosis.—They are chiefly distinguished from the Nyctaginaceæ by their habit and commonly ebracteate flowers.

Distribution and Numbers.—More or less distributed over the globe, but most abundant in extratropical regions. *Illustrative Genera:*—Salicornia, *Tourn.*; Beta, *Tourn.*; Salsola, *Linn.* There are above 500 species.

Properties and Uses.—Several plants of this order inhabit salt-marshes, and yield by combustion an ash called *barilla*, from which carbonate of soda was formerly principally obtained; but their use for this purpose has much fallen off of late years, in consequence of soda being more readily extracted from other sources. The plants which thus yield barilla principally belong to the genera *Salsola*, *Salicornia*, *Chenopodium*, and *Atriplex*. Many plants of the order are esculent, as Beet and Mangel-Wurzel or Mangold Wurzel; and some are used as pot-herbs, as Spinach or Spinage (*Spinacia oleracea*), Garden Orache or Mountain Spinach (*Atriplex hortensis*), and English Mercury (*Chenopodium Bonus-Henricus*). The seeds of others are nutritious; and several contain volatile oil, which renders them anthelmintic, antispasmodic, aromatic, carminative, or stimulant.

Order 4. BASELLACEÆ, the Basella Order.—*Diagnosis.*—

This is a small order of climbing herbs or shrubs closely allied to Chenopodiaceæ, but chiefly distinguished by its plants having two rows of coloured sepals, and by their stamens being evidently perigynous. There are about 12 species, all of which are tropical plants. *This is made a sub-order of Chenopodiaceæ by Bentham and Hooker.*

Properties and Uses.—*Basella rubra* and *B. alba* are used in the East Indies as a substitute for Spinach. From the former species a purple dye may be also obtained. The fleshy roots of *Ullucus tuberosus* or *Melloca tuberosa* are largely used in Peru and some of the adjoining countries as a substitute for the Potato.

Order 5. PHYTOLACCACEÆ, the Phytolacca Order.—Character.—*Herbs* or *undershrubs. Leaves* alternate, entire, exstipulate. *Flowers* hermaphrodite or very rarely unisexual, racemose. *Calyx* 4—5-partite. *Stamens* nearly or quite hypogynous, either equal in number to the divisions of the calyx and alternate with them, or more numerous; *anthers* 2-celled. *Ovary* superior, composed of 2 or more carpels, distinct or more or less combined; *styles* and *stigmas* distinct, equal in number to the carpels. *Fruit* dry or succulent, each carpel of which it is composed containing 1 ascending seed; *embryo* curved round mealy albumen; *radicle* next the hilum.

Distribution and Numbers.—Natives principally of America, India, and Africa. *Illustrative Genera*:—Giesekia, *Linn.*; Phytolacca, *Tourn.* There are about 80 species.

Properties and Uses.—An acrid principle is more or less diffused throughout the plants of this order; but this is frequently destroyed by boiling in water. Some are emetic and purgative.

Order 6. PETIVERIACEÆ, the Petiveria Order.—*Diagnosis, &c.*—This is a small order of plants, which is included by some botanists, as Bentham and Hooker, in Phytolaccaceæ, with which it agrees in many particulars. It is distinguished from that order by having stipulate leaves, an ovary formed of a single carpel, exalbuminous seeds, and a straight embryo with convolute cotyledons. These plants are natives of tropical America. There are about 12 species in this order.

Properties and Uses.—Most of the species are acrid, and some have a strong alliaceous odour.

Order 7. BATIDACEÆ, the Batis Order.—This supposed distinct order only contains a single plant, the *Batis maritima*, a succulent shrubby species, with opposite leaves, and unisexual flowers arranged in amenta; it is a native of the West Indies,

where it is occasionally used as an ingredient in pickles. Its ashes also yield barilla. Some authors regard this genus as belonging to Chenopodiaceæ.

Order 8. POLYGONACEÆ, the Buckwheat Order.—Character.—*Herbs* or rarely *shrubs*. *Leaves* alternate, simple, commonly with ochreate stipules above the swollen joints (*nodes*) of the stem, or rarely exstipulate. *Flowers* perfect, or sometimes unisexual. *Calyx* inferior of from 3—6 sepals, more or less persistent, imbricate. *Stamens* few, hypogynous or rarely perigynous; *anthers* dehiscing longitudinally. *Ovary* superior, 1-celled; *styles* and *stigmas* 2—3; *ovule* solitary, orthotropous. *Fruit* usually a triangular nut, and commonly enveloped in the persistent calyx. *Seed* solitary, erect; generally with farinaceous albumen.

Diagnosis.—Usually herbs with ochreate stipules. Leaves simple, alternate. Calyx inferior, persistent, imbricate. Stamens definite. Ovary 1-celled; styles and stigmas 2—3. Fruit

FIG. 997.

Fig. 997. Flower of a species of *Polygonum.*——*Fig.* 998. Pistil of a species of *Rumex.*

FIG. 998.

triangular. Seed solitary, erect, usually with mealy albumen, radicle superior.

Distribution and Numbers.—Generally diffused over the globe, and more particularly so in temperate regions. *Illustrative Genera*:—Rheum, *Linn.*; Polygonium, *Linn.*; Coccoloba, *Jacq.*; Rumex, *Linn.* There are about 500 species.

Properties and Uses.—Chiefly remarkable for the presence of acid, astringent, or purgative properties. The acidulous character is principally due to the presence of salts of oxalic acid. The fruits and roots of several species are more or less nutritious.

Series 2.—*Multiovulatæ aquaticæ.*

Order 9. PODOSTEMACEÆ, the Podostemon Order.—Character.—Aquatic *herbs* with the aspect of Mosses or Liverworts. *Leaves* minute and densely imbricate, or finely

divided. *Flowers* minute, generally hermaphrodite, or very rarely unisexual, spathaceous. *Calyx* absent, or of 3 sepals. *Stamens* 1 or many, hypogynous; *anthers* 2-celled. *Ovary* superior, 2—3-celled; *stigmas* 2—3; *ovules* ascending, numerous. *Fruit* capsular, ribbed, with parietal or axile placentation. *Seeds* numerous, exalbuminous, with a straight embryo.

Distribution and Numbers.—Principally natives of South America. *Illustrative Genera*:—Hydrostachys, *Thouars*; Podostemon, *L. C. R.* There are about 120 species.

Properties and Uses.—Unimportant. Some species of *Lacis* are used for food on the Rio Negro, &c., in South America; and other plants of the order are eaten by cattle and fish.

Series 3.—*Multiovulatæ terrestres.*

Order 10. NEPENTHACEÆ, the Pitcher-plant Order.—Character.—*Herbs* or somewhat *shrubby plants*. *Leaves* alternate, and when perfect, terminated by a pitcher which is provided with an articulated lamina. *Flowers* terminal, racemose, unisexual, diœcious. *Calyx* inferior, with four divisions. *Stamens* usually 16, united into a column; *anthers* 2-celled, extrorse. *Ovary* superior, 4-angled, 4-celled. *Fruit* a capsule, 4-celled, with loculicidal dehiscence. *Seeds* very minute, numerous, albuminous; *embryo* with an inferior radicle.

Distribution, Numbers, and Properties.—Natives of swampy ground in China and the East Indies. *Nepenthes*, Linn., is the only genus; it includes about 14 species. Their properties are unknown; but they are remarkable from their pitchers entrapping and digesting insects and other animal matters, in consequence of the formation of a digestive ferment by their glands.

Order 11. CYTINACEÆ, the Cistus-rape Order.—Character.—Root-parasites destitute of chlorophyll, and with a fungoid texture. *Flowers* hermaphrodite or unisexual, and either solitary and sessile or clustered at the end of a scaly stem. *Calyx* tubular at the base, 3—6-partite. *Anthers* sessile, opening longitudinally. *Ovary* 1-celled, inferior; *ovules* very numerous; *placentas* parietal. *Fruit* 1-celled, with numerous seeds embedded in pulp. *Seeds* with or without albumen; *embryo* minute, amorphous or dicotyledonous. *This and the next order are frequently combined together in one order, Cytinaceæ.*

Distribution and Numbers.—Parasitic on the roots of *Cistus*, and upon fleshy Euphorbiaceæ and other succulent plants. They occur in the South of Europe and Africa. *Illustrative*

Genera:—Cytinus, *Linn.*; Hydnora, *Thunb.* There are about 7 species.

Properties and Uses.—Some have astringent properties, as *Cytinus Hypocistis.* A kind of extract is made from this plant in the South of Europe, and used, under the name of *Succus Hypocistidis*, in diarrhœa, and for arresting hæmorrhage.—*Hydnora africana* has a putrid-animal odour, but when roasted it is eaten by the native Africans at the Cape of Good Hope.

Order 12. RAFFLESIACEÆ, the Rafflesia Order.—Character.—*Root-parasites*, devoid of chlorophyll, without evident stems or leaves, and with a fungoid texture. These plants consist essentially of flowers sessile upon the branches of trees, and surrounded by scaly bracts. The *flowers* are hermaphrodite, or unisexual and diœcious. *Calyx* 5-partite, tubular; the throat surrounded by a number of thickened scaly processes, which are either distinct from each other or united into a ring. *Anthers* placed upon a column which adheres to the calyx, 2-celled; and either distinct, and each opening by a pore, or united into a many-celled body, and opening by a common pore. *Ovary* 1-celled, inferior; *ovules* very numerous; *placentas* parietal. *Fruit* indehiscent. *Seeds* very numerous, with or without albumen; *embryo* amorphous or dicotyledonous. *This order, as mentioned above, is sometimes included in Cytinaceæ.*

FIG. 999. FIG. 1000.

FIG. 1001.

Fig. 999. Vertical section of the flower of the common Birthwort (*Aristolochia Clematitis*).——*Fig.* 1000. The gynœcium and andrœcium of the same. —— *Fig.* 1001. Transverse section of the seed.

Distribution and Numbers.—Parasitic upon the stems of *Cissi* in the East Indies, and on Leguminous plants in South America. *Illustrative Genera*:—Rafflesia, *R. Br.*; Brugmansia, *Blum.* There are about 16 species.

Properties and Uses.—Some have styptic and astringent properties. They are chiefly remarkable for their flowers, some of which are of gigantic size.

Order 13. ARISTOLOCHIACEÆ, the Birthwort Order.—Character.—*Herbs* or climbing *shrubs*. *Leaves* alternate. *Flowers* axillary, hermaphrodite, dull-coloured, regular or irregular.

Calyx tubular, superior, with a valvate æstivation. *Stamens* 6—12, arising from the top of the ovary, and more or less attached to the style; *anthers* adnate, extrorse. *Ovary* inferior, 3—6-celled with numerous ovules; *style* simple; *stigmas* radiating, and corresponding in number to the cells of the ovary. *Fruit* capsular or succulent, 3—6-celled. *Seeds* numerous, albuminous; *embryo* very minute.

Distribution and Numbers.—Sparingly distributed in several parts of the world, but most common in tropical South America. *Illustrative Genera:*—Asarum, *Tourn.*; Aristolochia, *Tourn.* There are about 130 species.

Properties and Uses.—These plants contain a bitter principle and a volatile oil, and generally possess tonic, stimulant, and acrid properties. Many of the species are regarded in various parts of the world as useful in the treatment of snake-bites.

Series 4.—*Micrembryeæ.*

Order 14. PIPERACEÆ, the Pepper Order.—Character.—*Herbs* or *shrubs* with jointed stems. *Leaves* opposite, whorled, or alternate, and with or without stipules. *Flowers* spiked, hermaphrodite or sometimes unisexual, achlamydeous, bracteate. *Stamens* 2 or more; *anthers* 1—2-celled. *Ovary* simple, 1-celled, with one erect orthotropous ovule; *stigma* sessile. *Fruit* more or less fleshy, 1-celled, 1-seeded. *Seed* erect; *embryo* embedded in endosperm at the apex of the seed, and on the outside of abundant perisperm.

Distribution and Numbers.—Natives exclusively of tropical regions, especially in America and the islands of the Indian Archipelago. *Illustrative Genus:*—Piper, *Linn.* There are above 600 species.

Properties and Uses.—The plants of this order are chiefly remarkable for acrid, pungent, aromatic, and stimulant properties. These qualities are principally found in their fruits, and are essentially due to the presence of an acrid volatile oil and resin. Some are narcotic, and others are reputed to be astringent and febrifugal.

Order 15. SAURURACEÆ, the Saururus Order.—Character.—Marshy *herbs*. *Leaves* entire, alternate, stipulate. *Flowers* spiked, achlamydeous, hermaphrodite. *Stamens* 3—6, hypogynous, persistent. *Ovaries* 3—4, usually more or less distinct, and each with a solitary erect ovule, or sometimes united and with a few ascending ovules. *Fruit* either consisting of 4

fleshy indehiscent achænia, or capsular and 3—4-celled. *Seeds* ascending, with a minute embryo in fleshy endosperm on the outside of hard mealy perisperm. *This order is included by Bentham and Hooker in Piperaceæ as the tribe Saurureæ.*

Distribution and Numbers.—Natives of North America, Northern India, and China. *Illustrative Genera :*—Saururus, *Linn.*; Houttuynia, *Thunb.* There are about 7 species.

Properties and Uses.—They have acrid properties, and are reputed to be emmenagogue. Some are also astringent.

Order 16. CHLORANTHACEÆ, the Chloranthus Order.—Character.—*Herbs* or *undershrubs* with jointed stems, which are tumid at the nodes. *Leaves* simple, opposite, sheathing, with small interpetiolar stipules. *Flowers* in terminal spikes, achlamydeous, with scaly *bracts*, hermaphrodite or unisexual. *Stamens* 1, or more and united. *Ovary* 1-celled with a solitary pendulous ovule. *Fruit* drupaceous. *Seed* pendulous, with a minute embryo at the apex of fleshy endosperm; *radicle* inferior.

Distribution and Numbers.—Natives of tropical regions. *Illustrative Genera :*—Hedyosmum, *Swartz*; Chloranthus, *Swartz.* There are about 15 species.

Properties and Uses.—Aromatic stimulant properties are the principal characteristics of the plants of this order.

Order 17. MYRISTICACEÆ, the Nutmeg Order.—Character.—*Trees.* *Leaves* alternate, exstipulate, entire, dotted, stalked, leathery. *Flowers* unisexual. *Calyx* inferior, leathery, 3—4-cleft; in the *female flower*, deciduous; *æstivation* valvate. *Male flower* with 3—12 stamens, or rarely more numerous; *filaments* distinct or monadelphous; *anthers* 2-celled, extrorse, distinct or united, with longitudinal dehiscence. *Female flower* with 1 or many superior distinct *carpels*, or rarely 2; each carpel with 1 erect ovule. *Fruit* succulent. *Seed* arillate, with copious oily-fleshy ruminated albumen; *embryo* small, with an inferior radicle.

Distribution and Numbers.—Natives of tropical India and America. *Illustrative Genera :*—Myristica, *Linn.*; Hyalostemma, *Wall.* There are above 40 species.

Properties and Uses.—Aromatic properties are almost universally found in the plants of this order, and more especially in their seeds. The bark and the pericarp are frequently acrid.

Order 18. MONIMIACEÆ, the Monimia Order.—*Diagnosis.*—Trees or shrubs, with opposite exstipulate leaves. Flowers axillary, unisexual. The flowers generally resemble those of the

Atherospermaceæ, but they differ in always being unisexual; in the longitudinal dehiscence of their anthers; in the absence of feathery styles to the fruit; and in their ovules and seeds being pendulous.

Distribution and Numbers.—They are principally natives of South America, but are found also in Australia, Java, Madagascar, Mauritius, and New Zealand. *Illustrative Genera*:—Monimia, *Thouars*; Peumus, *Pers.* There are about 40 species.

Properties and Uses.—They are aromatic fragrant plants, but their properties are of no great importance.

Order 19. ATHEROSPERMACEÆ, the Plume Nutmeg Order.—Character.—*Trees*, with opposite exstipulate *leaves*. *Flowers* axillary, racemose, bracteate, unisexual or rarely perfect. *Calyx* inferior, tubular, with several divisions. *Male flowers* with numerous perigynous stamens; *anthers* 2-celled, opening by recurved valves. *Female flowers* usually with abortive scaly *stamens*. *Carpels* superior, numerous, distinct, each with a solitary erect ovule; *styles* and *stigmas* as many as the carpels. *Fruit* consisting of a number of achænia crowned with the persistent feathery styles, and enclosed in the tube of the calyx. *Seeds* erect, with a minute embryo at the base of fleshy albumen. *This order is combined with Monimiaceæ by Bentham and Hooker.*

FIG. 1002.

Fig. 1002. Vertical section of the female flower of *Laurus nobilis*, the Sweet Bay.

Distribution and Numbers.—Natives of Australia and Chili. There are but 3 genera: namely, Atherosperma, *Labill.*, and Doryphora, *Endl.*, from Australia; and Laurelia, *Juss.*, from Chili. These include four species.

Properties and Uses.—They are fragrant plants. The achænia of *Laurelia* somewhat resemble common Nutmegs in their odour.

Series 5.—*Daphnales.*

Order 20. LAURACEÆ, the Laurel Order.—Character.—Aromatic *trees* or *shrubs* (parasitic and twining in *Cassytha*). *Leaves* simple, exstipulate, usually alternate, sometimes dotted (*Cassytha* has scales instead of foliage leaves). *Flowers* generally hermaphrodite or sometimes unisexual. *Calyx* inferior, deeply 4—6-cleft, coloured, in two whorls, the limb sometimes obsolete; *æstivation* imbricate. *Stamens* perigynous, definite, some always

sterile ; *filaments* distinct, the inner ones commonly with glands at their base ; *anthers* adnate, 2—4-celled, *l*, *l*, dehiscing by recurved valves, *v*. *Ovary* superior, 1-celled, with 1 or 2 suspended ovules. *Fruit* baccate or drupaceous. *Seeds* exalbuminous; *embryo* with large cotyledons, and a superior radicle.

Distribution and Numbers.—They are chiefly natives of tropical regions, but a few occur in North America, and one (*Laurus nobilis*) in Europe. *Illustrative Genera* :—Cinnamomum, *Burm.* ; Nectandra, *Rottb.*; Laurus, *Tourn.* There are above 450 species.

Properties and Uses.—The plants of this order are almost universally characterised by the possession of aromatic properties, which are due to the presence of volatile oils; many of them are therefore employed as aromatic stimulants. Others are narcotic ; some have sudorific properties; and several are tonic, stomachic, febrifugal, or astringent. A few have edible fruits, and many yield valuable timber.

FIG. 1003.

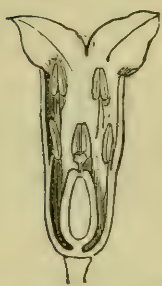


Fig. 1003. Vertical section of the flower of a species of *Daphne*.

Order 21. PROTEACEÆ, the Protea Order. —Character.—*Shrubs* or small *trees*. *Leaves* hard, dry, opposite or alternate, exstipulate. *Flowers* usually hermaphrodite. *Calyx* inferior, 4-partite or of 4 sepals ; *æstivation* valvate. *Stamens* perigynous, equal in number to the partitions of the calyx and opposite to them ; *anthers* bursting longitudinally. *Ovary* simple, superior, 1-celled, with 1 or more ovules, ascending or suspended. *Fruit* dehiscent or indehiscent. *Seeds* exalbuminous ; *embryo* straight, *radicle* generally inferior.

Distribution and Numbers.—Natives chiefly of Australia and the Cape of Good Hope. *Illustrative Genera* :—Protea, *Linn.* ; Banksia, *Linn. fil.* There are more than 600 species.

Properties and Uses.—They are chiefly remarkable for the beauty or singularity of their flowers and their evergreen foliage. But the fruits and seeds of some species are eaten ; and the wood is largely employed at the Cape and in Australia for burning, and occasionally for other purposes ; thus, that of *Protea grandiflora* is used at the Cape of Good Hope for wagon-wheels, hence the plant is named Wagenboom. The seeds of *Macadamia ternifolia*, a native of Queensland, are edible.

Order 22. THYMELACEÆ, the Mezereon Order.—Character.

—*Trees*, *shrubs*, or very rarely *herbs*, with an acrid very tough bark. *Leaves* entire, exstipulate. *Flowers* hermaphrodite or rarely unisexual. *Calyx* inferior, regular, coloured, tubular, 4—5-lobed; *æstivation* imbricate. *Stamens* perigynous, twice as many as the divisions of the calyx, or equal in number to them, or fewer, in the two latter cases they are opposite to the lobes of the calyx; *anthers* 2-celled, bursting longitudinally. *Ovary* superior, simple, 1-celled, with a solitary suspended ovule. *Fruit* dry and nutlike, or drupaceous. *Seed* suspended: *albumen* none or but small in quantity; *embryo* straight, with a superior radicle.

Distribution and Numbers.—They are found more or less abundantly in all parts of the world, but especially in Australia and the Cape of Good Hope. *Illustrative Genera*:—Daphne, *Linn.*; Pimelea, *Banks et Sol.* There are about 300 species.

Properties and Uses.—The plants of this order are chiefly remarkable for the toughness and acridity of their bark. The fruit of *Dirca palustris* is narcotic, and that of the plants generally of the order poisonous or suspicious; but the seeds of *Inocarpus edulis* are said to resemble Chestnuts in flavour when roasted. Several species of *Daphne*, *Pimelea*, and other genera, are handsome shrubby plants.

Order 23. AQUILARIACEÆ, the Aquilaria Order.—Character.—*Trees* with entire exstipulate *leaves*. *Calyx* tubular or top-shaped, 4—5-lobed, imbricate, persistent. *Stamens* perigynous, 10, 8, or 5, opposite the lobes of the calyx when equal to them in number; *anthers* 2-celled, opening longitudinally. *Ovary* superior, usually 2-celled; *ovules* 2, suspended; or rarely 1-celled with parietal placentation. *Fruit* generally 2-valved, capsular, sometimes succulent and indehiscent. *Seeds* usually 2, or rarely 1 by abortion; exalbuminous. *This order is sometimes included in Thymelaceæ.*

Distribution and Numbers.—Natives exclusively of tropical Asia. *Illustrative Genera*:—Aquilaria, *Lam.*; Leucosmia, *Benth.* There are about 10 species.

Properties and Uses.—Some species yield a fragrant stimulant resin.

Order 24. PENÆACEÆ, the Penæa Order.—Character.—Evergreen *shrubs*, with opposite, exstipulate, imbricate leaves. *Flowers* hermaphrodite. *Calyx* inferior, bracteate, 4-lobed; *æstivation* valvate or imbricate. *Stamens* perigynous, 4 or 8, alternate with the divisions of the calyx when equal to them in number. *Ovary* superior, 4-celled; *style* 1; *stigmas* 4, with

appendages on one side. *Fruit* 4-celled, dehiscent or indehiscent. *Seeds* varying in position, exalbuminous; *embryo* with very minute cotyledons.

This order is sometimes placed near Proteaceæ, but it is especially distinguished from that order by its 4-*celled ovary and* 4-*celled fruit.*

Distribution and Numbers.—They are only found at the Cape of Good Hope. *Illustrative Genera:*—Penæa, *Linn.*; Geissoloma, *Lindl.* There are over 20 species.

Properties and Uses.—Unimportant.

Order 25. ELÆAGNACEÆ, the Oleaster Order.—Character.—*Small trees* or *shrubs*, with entire exstipulate usually very scurfy *leaves*. *Flowers* mostly unisexual or rarely perfect. *Male flowers* amentaceous, bracteate. *Sepals* 2—4, distinct or united. *Stamens* definite perigynous. *Female flowers* with an inferior tubular calyx, and a fleshy disk; *æstivation* imbricate. *Ovary* superior, 1-celled, with a solitary ascending ovule. *Fruit* enclosed in the succulent calyx, indehiscent. *Seed* solitary, ascending, with thin albumen; *embryo* straight, with an inferior radicle.

Distribution and Numbers.—They are generally diffused throughout the northern hemisphere, and rare in the southern, *Illustrative Genera:*—Hippophaë, *Linn.*; Elæagnus, *Linn.* There are about 30 species.

Properties and Uses.—Unimportant. The fruits of *Elæagnus orientalis* are esteemed in Persia under the name of *zinzeyd*; and those of *E. arborea*, *E. conferta*, and others are eaten in certain parts of India. Those also of *Hippophaë rhamnoides*, the Sea-Buckthorn, which is a native of England, are also edible, and have been employed in the preparation of a sauce for fish, but their use requires caution from containing a narcotic principle.

Series 6.—*Achlamydosporeæ.*

Order 26. LORANTHACEÆ, the Mistletoe Order.—Character.—*Parasitic shrubs*. *Leaves* greenish, commonly opposite, exstipulate. *Flowers* hermaphrodite, or unisexual and diœcious. *Calyx* superior, with 4—8 divisions; *æstivation* valvate; sometimes absent. *Stamens* opposite to the lobes of the calyx and equal to them in number. *Ovary* inferior, 1-celled, with 3 ovules, suspended from a free-central placenta, or 1 erect and arising from the base of the ovary. Ovules without integuments. *Fruit* commonly succulent, 1-celled, with a solitary seed; *embryo* in fleshy albumen, with the radicle remote from the hilum.

Distribution and Numbers.—They are principally found in the hotter parts of America and Asia. Three species are natives of Europe, and a few occur in Africa and some other regions. *Illustrative Genera*:—Myzodendron, *Sol.*; Viscum, *Tourn.*; Loranthus, *Linn.* There are above 400 species.

Properties and Uses.—Unimportant. Some are astringent.

Order 27. SANTALACEÆ, the Sandal-wood Order.—Character.—*Herbs*, *shrubs*, or *trees*. *Leaves* entire, alternate. *Flowers* usually hermaphrodite. *Calyx* superior, 4—5-cleft, valvate in æstivation. *Stamens* perigynous opposite to the segments of the calyx and equal to them in number. *Ovary* 1-celled, inferior; *ovules* 1—4, without integuments; *placenta* free-central. *Fruit* indehiscent, 1-seeded. *Seed* with a quantity of fleshy albumen; *embryo* straight, minute; *radicle* superior.

Distribution and Numbers.—Natives of various parts of the world. The species found in North America and Europe are inconspicuous herbs; those of India, Australia, &c., are trees or shrubs. The genus *Thesium* is partially parasitic on the roots of other plants. *Illustrative Genera*:—Thesium, *Linn.*; Santalum, *Linn.* There are about 120 species.

Properties and Uses.—Some of these plants, as *Thesium*, are slightly astringent; others have a fragrant wood; and a few produce edible fruits and oily seeds.

Order 28. BALANOPHORACEÆ, the Balanophora Order.—Character.—Leafless root-parasites with amorphous fungoid stems of various colours, but never green; and underground more or less fleshy tubers or rhizomes. *Peduncles* naked or scaly, bearing spikes of flowers, which are commonly unisexual, bracteate, and of a white colour. *Male flowers* very evident, each with a tubular *calyx*, which is either entire or 3—5-lobed. *Stamens* usually 3—5, or sometimes 1, in the former case more or less united or distinct. *Female flowers* very minute, with a tubular superior *calyx*, the limb either wanting or present and bilabiate. *Ovary* inferior, usually 1-celled; *styles* 2; *ovule* solitary, pendulous. *Fruit* small, more or less compressed, indehiscent. *Seed* solitary, albuminous, with a lateral undivided or amorphous *embryo*.

Distribution and Numbers.—These plants are parasitical on the roots of various Dicotyledonous plants, especially in the tropical and sub-tropical mountains of Asia and South America. Other species are found in different parts of Africa, Australia, &c. *Illustrative Genera*:—Cynomorium, *Michel*; Balanophora, *Forst.* There are, according to Sir Joseph Hooker, 37 species.

Properties and Uses.—Many are remarkable for their astringent properties; others are edible, as *Ombrophytum*, a native of Peru, and *Lophophytum* of Bolivia; and some secrete a kind of wax.

Series 7.—*Unisexuales.*

Order 29. EUPHORBIACEÆ, the Spurge Order.—Character.—*Trees*, *shrubs*, or *herbs*, usually with an acrid milky juice. *Leaves* alternate or opposite, simple or rarely compound, stipulate or exstipulate. *Flowers* unisexual, monœcious, or diœcious, axillary or terminal, sometimes enclosed in a calyx-like involucre; achlamydeous, or with a lobed inferior calyx having on its inside glandular or scaly appendages, or even

FIG. 1004.

FIG. 1005.

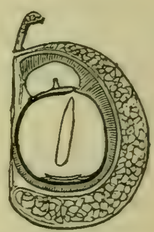


Fig. 1004. Monœcious head of flowers of a species of *Euphorbia*. *i.* Involucre, a portion of which has been removed in front. *g, g.* Glands on the divisions of the involucre. *b, b.* Scales or bractlets at the base of the flowers. *fm, fm.* Male flowers, each consisting of a stamen supported on a pedicel, to which it is articulated. *ff.* Female flower, supported on a stalk. From Jussieu.——*Fig.* 1005. Vertical section of the pericarp and seed of a carpel (*coccus*) of a species of *Euphorbia*.

evident petals, which are either distinct or united. *Male flowers* consisting of 1 or more *stamens*, distinct or united into one or more bundles; *anthers* 2-celled. *Female flowers* with a superior *ovary*, which is either elevated upon a stalk or sessile, 1- 2- 3- or many-celled; *styles* either absent or corresponding in number to the cells of the ovary, entire or divided; *stigmas* equal in number to the cells of the ovary, or, when the styles are divided, corresponding in number to their divisions; *ovules* 1 or 2 in each cell, suspended from the inner angle. *Fruit* either dry, and its component carpels then separating from each other and from the axis and usually opening with elasticity; or succulent and indehiscent. *Seeds* 1 or 2 in each cell, suspended,

often caruneulate; *embryo* straight, in fleshy albumen, with flattened cotyledons, and a superior radicle.

Diagnosis.—Herbs, shrubs, or trees, commonly with an acrid milky juice. Flowers unisexual, monœcious or diœcious. Calyx absent, or present and inferior. Petals rarely present. Male flowers with one or more stamens, distinct or united, and 2-celled anthers. Female flowers with a superior, sessile or stalked, 1- or more-celled ovary, and with 1 or 2 suspended ovules in each cell. Fruit of 1, 2, 3, or many dry carpels, which separate from the axis and from each other, and usually open with elasticity; or fleshy and indehiscent. Seeds suspended; embryo in fleshy albumen, straight, with flattened cotyledons, and a superior radicle.

Distribution and Numbers.—They are more or less distributed over the globe, and are especially abundant in equinoctial America. *Illustrative Genera :*—Euphorbia, *Linn.*; Mercurialis, *Linn.*; Ricinus, *Tourn.*; Buxus, *Tourn.* There are above 2,500 species.

Properties and Uses.—These plants generally contain an acrid poisonous principle or principles, which is found more or less in all their parts. Some are very deadly poisons. But in proper doses many are used medicinally as emetics, purgatives, diuretics, or rubefacients. A pure starch, which is largely employed for food, may be obtained from some plants of the order, while india-rubber may be procured from the milky juice of others. A few are entirely devoid of any acrid or poisonous principle, and are used medicinally as aromatic tonics. Some have edible roots; others yield dyeing agents; and several are valuable on account of their wood.

Order 30. Scepaceæ, the Scepa Order.—*Diagnosis.*—This order is closely allied to Euphorbiaceæ, *in which it is included by Bentham and Hooker*, but from which it is readily distinguished by its flowers being *amentaceous*.

Distribution, Numbers, and Properties.—Natives of the East Indies. There are 6 species. The wood of *Scepa* (*Lepidostachys*) *Roxburghii* is called Cocus or Kokra. It is very hard, and is chiefly employed for flutes and similar musical instruments.

Order 31. Stilaginaceæ, the Stilago Order.—Character.—*Trees* or *shrubs*. *Leaves* alternate, simple, leathery, with deciduous stipules. *Flowers* minute, unisexual, in scaly spikes. *Calyx* 2—5-partite. *Male flowers* consisting of 2 or more *stamens* on an enlarged thalamus; *anthers* usually 2-lobed, with a fleshy connective, and dehiscing transversely at the apex.

Female flowers with a superior 1—2-celled *ovary*, each cell with 2 suspended *ovules*. *Fruit* drupaceous. *Seeds* suspended, albuminous; *embryo* straight, with leafy cotyledons, and a superior radicle. *This order is made a tribe of Euphorbiaceæ by Bentham and Hooker.*

Distribution and Numbers.—Natives of Madagascar and the East Indies. *Illustrative Genera:*—Stilago, *Linn.*; Falconeria, *Royle.* There are about 20 species.

Properties and Uses.—Unimportant. The fruits of *Antidesma pubescens* and *Stilago Bunias* are subacid and agreeable.

Order 32. URTICACEÆ, the Nettle Order.—Character.—*Herbs*, *shrubs*, or *trees*, with a watery juice. *Leaves* opposite or alternate, usually rough or with stinging glands; stipulate

FIG. 1006.

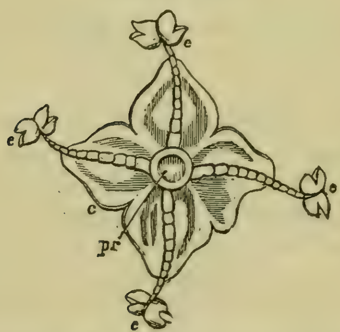


FIG. 1007.

Fig. 1006. Male flower of the Small Nettle (*Urtica urens*). *c.* Calyx. *e, e, e, e.* Stamens, with 2-celled anthers. *pr.* Rudimentary ovary.—*Fig.* 1007. Vertical section of the ovary of the female flower of the same. *p.* Wall of the ovary. *s.* Stigma. *o.* Ovule.

or rarely exstipulate. *Flowers* small, unisexual (*fig.* 1006) or rarely hermaphrodite, scattered or arranged in heads or catkins. *Calyx* inferior, lobed, persistent. *Male flower* with a few distinct stamens, perigynous, opposite the divisions of the calyx, and with a rudimentary ovary; *filaments* at first incurved. *Female flower* with a superior 1-celled ovary; *ovule* erect, orthotropous. *Fruit* indehiscent, surrounded by the persistent calyx. *Seed* solitary, erect; *embryo* straight, enclosed in albumen; and with a superior *radicle.*

Bentham and Hooker, in 'Genera Plantarum,' include the four succeeding orders—Moraceæ, Cannabinaceæ, Artocarpaceæ, and Ulmaceæ—in Urticaceæ, as sub-orders.

Distribution and Numbers.—These plants are more or less distributed over the world. *Illustrative Genera:*—Urtica,

Tourn.; Parietaria, *Tourn.* The order contains more than 300 species.

Properties and Uses.—Chiefly remarkable for yielding valuable fibres, and for the acrid stinging juice contained in their glands.

Order 33. MORACEÆ, the Mulberry Order.—Character.—*Trees* or *shrubs* with a milky juice. *Leaves* with large stipules. *Flowers* unisexual, in heads, spikes, or catkins. *Male flowers* with a 3—4-partite *calyx*, or achlamydeous. *Stamens* 3—4, perigynous, and opposite the segments of the calyx; *anthers* usually inflexed. *Female flowers* with 3—5 *sepals. Ovary* superior 1—2-celled. *Fruit* a sorosis or syconus. *Seed* solitary, pendulous; *embryo* hooked in fleshy albumen, and with a superior radicle.

Distribution and Numbers.—They are natives of both hemispheres, and occur in temperate and tropical climates. *Illustrative Genera:*—Morus, *Tourn.*; Dorstenia, *Plum.* There are over 200 species.

FIG. 1008. FIG. 1009.

Fig. 1008. Male flower of the Black Mulberry (*Morus nigra*).——*Fig.* 1009. Vertical section of the ovary of the female flower of the same.

Properties and Uses.—The milky juice of some species possesses acrid and poisonous properties, while in others it is bland, and may be taken as a beverage. From the milky juice of some caoutchouc or india-rubber is obtained. The inner bark of other species supplies fibres. Some possess stimulant, sudorific, tonic, or astringent properties. Many yield edible fruits, while the seeds generally of the plants of this order are wholesome.

Order 34. CANNABINACEÆ, the Hemp Order.—Character.—Rough *herbs*, erect or twining, with a watery juice. *Leaves* opposite or alternate, simple or compound, stipulate, often glandular. *Flowers* small, unisexual, diœcious. *Male flowers* in racemes or panicles. *Calyx* scaly, imbricate. *Stamens* 5, opposite the sepals; *filaments* filiform. *Female flowers* in spikes or strobiles, each flower with 1 sepal surrounding the ovary, which is superior and 1-celled, and containing a solitary pendulous campylotropous ovule. *Fruit* dry, indehiscent. *Seed* solitary, pendulous, without albumen; *embryo* curved or spirally coiled, with a superior radicle.

Distribution and Numbers.—Natives of the temperate parts of the northern hemisphere in Europe and Asia. *Illustrative Genera*:—Cannabis, *Tourn.*; Humulus, *Linn.* These are the only genera, and each contains but one species.

Properties and Uses.—The plants of this order yield valuable fibres and possess narcotic, stomachic, and tonic properties.

Order 35. ARTOCARPACEÆ, the Bread-fruit Order.—Character.—*Trees* or *shrubs* with a milky juice. *Leaves* alternate, simple, with large convolute stipules. *Flowers* unisexual, in dense heads on a fleshy receptacle. *Male flowers* achlamydeous, or with a 2—4-lobed or 2—4-sepaled calyx. *Stamens* opposite the lobes of the calyx or to the sepals; *anthers* erect. *Female flowers* arranged on a fleshy receptacle of varying form. *Calyx* inferior, tubular, 2–4-cleft or entire. *Ovary* superior, 1-celled. *Fruit* commonly a sorosis. *Seed* erect or pendulous, with little or no albumen; *embryo* straight, with a superior radicle.

FIG. 1010.

Fig. 1010. Branch of the Bread-fruit tree (*Artocarpus incisa*). *a*, *c*. Heads of female or pistillate flowers. *b*. Head of staminate or male flowers.

Distribution and Numbers. — Exclusively tropical plants. *Illustrative Genera*: Antiaris, *Leschen.*; Artocarpus, *Linn.* There are about 60 species.

Properties and Uses.—The milky juice of several species yields india-rubber. This juice is in certain cases poisonous, while in others it forms a nutritious beverage. A few yield valuable timber. The fruits of some are edible, and the seeds generally of plants of this order are wholesome.

Order 36. ULMACEÆ, the Elm Order.—Character.—*Trees* or *shrubs* with a watery juice. *Leaves* alternate, simple, scabrous, with deciduous stipules. *Flowers* hermaphrodite or unisexual, in loose clusters. *Calyx* inferior, membranous, imbricate. *Stamens* perigynous, definite; *anthers* erect. *Ovary* superior, 1—2-celled; *styles* or *stigmas* 2. *Fruit* indehiscent, samaroid or drupaceous, 1—2-celled. *Seeds* solitary, pendulous,

with little or no albumen; *embryo* straight; *cotyledons* foliaceous; *radicle* superior.

Division of the Order and Illustrative Genera.—This order may be divided into two sub-orders or tribes as follows:—Sub-order 1. *Celteæ.*—Ovary 1-celled, with drupaceous fruit. *Illustrative Genera:*—Celtis, *Tourn.*; Mertensia, *H. B. K.* Sub-order 2. *Ulmeæ.*—Ovary 2-celled, with usually samaroid fruit. *Illustrative Genera:*—Planera, *Gmel.*; Ulmus, *Linn.*

Distribution and Numbers.—They are chiefly natives of the northern regions of the world. There are about 60 species.

Properties and Uses.—Some are valuable timber trees. The bark and fruit of others are bitter, tonic, and astringent; and a few possess aromatic properties.

Order 37. PLATANACEÆ, the Plane Order.—Character. — *Trees* with a watery juice. *Leaves* alternate, palmately lobed, with deciduous sheathing stipules. *Flowers* unisexual, monœcious in globular amentaceous heads; achlamydeous. *Male flowers* with 1 *stamen* and a two-celled linear *anther*. *Female flowers* consisting of a 1-celled *ovary* and a thick *style*; *ovules* 1—2, pendulous. *Fruits* arranged in a compact rounded head, consisting of clavate achænia with persistent styles. *Seeds* 1 or rarely 2, pendulous; *embryo* straight, in very thin albumen, with an inferior radicle.

FIG. 1011.

Fig. 1011. Branch of the Plane tree (*Platanus orientalis*), with amentaceous heads of achlamydeous female flowers.

Distribution and Numbers.—They are natives principally of North America and the Levant. *Platanus*, Linn., is the only genus, of which there are 5 or 6 species.

Properties and Uses.—Of no particular importance, except that, from their being large handsome trees, and flourishing well in large towns, they are commonly planted in our parks and squares. The leaves closely resemble in appearance those of

the Sycamore tree. The timber is sometimes used by the cabinet-maker.

Order 38. JUGLANDACEÆ, the Walnut Order.—Character.—*Trees*. *Leaves* alternate, pinnate, exstipulate. *Flowers* unisexual. *Male flowers* in amenta; with an irregular calyx, or a simple scale. *Female flowers* solitary, or in small terminal clusters, or amenta, without a cupule; *calyx* superior, regular, 3—5-lobed; *ovary* inferior, 2—4-celled at the base, 1-celled above; *ovule* solitary, erect, orthotropous. *Fruit* called a tryma. *Seed* 2—4-lobed, exalbuminous; *embryo* with sinuous oily cotyledons, and a short superior radicle.

Distribution and Numbers.—Chiefly natives of North America, but a few are found in the East Indies, Persia, and the

FIG. 1012.

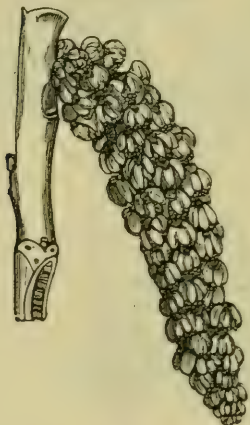


FIG. 1013.

Fig. 1012. Staminate amentum of the Walnut tree (*Juglans regia*): the flowers are separated by scaly bracts.——*Fig*. 1013. Seed of the Walnut tree.

Caucasus. *Juglans regia*, the Walnut tree, is a native of the countries between Greece and Cashmere. *Illustrative Genera*:—Juglans, *Linn.*; Carya, *Nutt.* There are about 30 species.

Properties and Uses.—Chiefly important for their valuable timber, and for their oily edible seeds.

Order 39. MYRICACEÆ, the Bog-myrtle Order.—Character. *Shrubs* or small *trees*, with alternate, simple, resinous-dotted leaves, which are usually exstipulate. *Flowers* unisexual, amentaceous, monœcious or diœcious, both kinds of flowers in the same or in different catkins. *Male flowers* achlamydeous; *stamens* definite. *Female flowers* achlamydeous, with a 1-celled sessile *ovary*, 2 *styles*, and 1 erect orthotropous *ovule*; *fruit* drupaceous; *seed* solitary, erect, without hairs; *embryo* without albumen; *radicle* superior.

Distribution and Numbers.—Natives of the temperate parts of Europe and North America, and of the tropical regions of South America, India, and the Cape of Good Hope. *Illustrative Genera:*—Myrica, *Linn.*; Comptonia, *Banks.* There are about 20 species.

Properties and Uses.—The plants of this order are chiefly remarkable for aromatic and astringent properties.

Order 40. CASUARINACEÆ, the Beef-wood Order.—Character.—*Trees* with pendulous, jointed, striated branches, without evident *leaves*, but sometimes having short toothed sheaths, representing whorls of leaves, at the nodes. *Flowers* in bracteate spikes or heads, unisexual. *Male flowers* with 2 *sepals* united at their points, and 2 alternating *bracts*; 1 *stamen*, and a 2-celled *anther*. *Female flowers* in dense spikes or heads, naked, but each having 2 *bracts*; *ovary* 1-celled or rarely 2-celled, with 1—2 ascending *ovules*, and 2 *styles*. *Fruits* winged, indehiscent,

FIG. 1014.

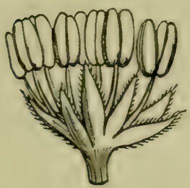


FIG. 1015.

FIG. 1016.

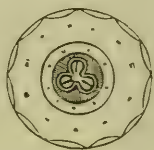


Fig. 1014. Male flower of a species of Oak (*Quercus*).——*Fig.* 1015. Female flower of the same.——*Fig.* 1016. Transverse section of the female flower.

collected together into a cone-shaped body hidden under the thickened bracts. *Seeds* exalbuminous; *radicle* superior.

Distribution and Numbers.—These plants are principally natives of Australia. They are called Beef-wood trees from the colour of their timber somewhat resembling that of raw beef. In general appearance they much resemble the branched Equisetinæ. *Casuarina*, Linn., is the only genus; it contains about 32 species.

Properties and Uses.—The species of *Casuarina* yield very hard and heavy timber, and the bark of some is said to be tonic and astringent.

Order 41. CORYLACEÆ or CUPULIFERÆ, the Oak Order.—Character.—*Trees* or *shrubs*. *Leaves* alternate, usually feather-veined, simple, with deciduous stipules. *Flowers* monœcious. *Male flowers* clustered or in amenta, and with or without bracts; *stamens* 5—20, inserted into the base of a membranous calyx, or of scales or bracts. *Female flowers* solitary or amentaceous,

and surrounded by an involucre of bracts, which ultimately form a cupule round the ovary and fruit; *ovary* inferior, surmounted by a rudimentary calyx, 3- or more-celled; *ovules* 2 in each cell or solitary, pendulous or peltate; *stigmas* almost sessile. *Fruit* a glans or nut, 1-celled by abortion, more or less enclosed by the cupule. *Seeds* large, 1 or 2, exalbuminous; *cotyledons* thick, fleshy or farinaceous; *radicle* superior.

Bentham and Hooker include the order Betulaceæ in the Cupuliferæ, and divide the order as thus constituted into three tribes as follows:—Tribe 1. Betuleæ. Tribe 2. Coryleæ. Tribe 3. Quercineæ.

The Betuleæ are at once distinguished by their superior ovary and the absence of a cupule from the two latter; and the Coryleæ from the Quercineæ by the male flowers being achlamydeous, and having one ovule in each cell of the ovary; the latter having a 3—7-lobed ovary, and 2 ovules in each cell.

Some authors, again, divide this order into two orders—Corylaceæ and Cupuliferæ.

Distribution and Numbers.—They abound in the forests of temperate regions. A few occur in the high lands of tropical and hot climates. *Illustrative Genera:*—Carpinus, *Tourn.*; Corylus, *Tourn.*; Quercus, *Tourn.* There are nearly 300 species.

Properties and Uses.—Most important on account of their valuable timber. Many yield edible seeds, and some have highly astringent barks and cupules.

Order 42. BETULACEÆ, the Birch Order.—Character.—*Trees* or *shrubs*. *Leaves* simple, alternate, with deciduous stipules. *Flowers* small, unisexual, monœcious, amentaceous, with no true *calyx*, but in its place small scaly *bracts*, which in some cases are arranged in a whorled manner. *Male flowers* with 2 or 3 *stamens* opposite the bracts. *Female flowers* with a 2-celled *ovary*, and 1 pendulous anatropous *ovule* in each cell. *Fruit* dry, thin, indehiscent, often winged, 1—2-celled, 1-seeded, without a cupule. *Seed* pendulous, exalbuminous; *embryo* straight; *radicle* superior. *Bentham and Hooker include this order in Cupuliferæ as the tribe Betuleæ.*

Distribution and Numbers.—They are principally natives of the colder regions in the northern hemisphere. *Illustrative Genera:*—Betula, *Linn.*; Alnus, *Tourn.* These are the only genera: there are about 70 species.

Properties and Uses.—They are valuable for their timber, and for their astringent, tonic, and febrifugal barks.

Series 8.—*Ordines Anomali.*

Order 42. SALICACEÆ, the Willow Order.—Character—*Trees* or *shrubs*. *Leaves* simple, alternate, deciduous, with persistent or deciduous stipules. *Flowers* unisexual, diœcious, amentaceous, naked, or with a membranous or cup-like *calyx*. *Male flowers* with 1—30 stamens, distinct or monadelphous. *Female flowers* sessile or stalked, with a superior 1-celled *ovary*, and numerous erect anatropous *ovules* on 2 parietal placentas. *Fruit* 1-celled, 2-valved, dehiscing loculicidally. *Seeds* minute, numerous, with long silky hairs springing from a funicle and covering the seed, exalbuminous; *embryo* erect, with an inferior radicle.

FIG. 1017. FIG. 1018.

Fig. 1017. Male flower of a species of Willow (*Salix*), with two stamens and a single bract at their base. —*Fig.* 1018. Female flower of the same with bract at the base, and a solitary stalked ovary and style surmounted by two stigmas.

Distribution and Numbers.—Chiefly natives of cold and temperate climates. *Illustrative Genera*:—Salix, *Tourn.*; Populus, *Tourn.* These are the only genera; there are about 250 species.

Properties and Uses.—Many species are either valuable for their timber, or for basket-work and other economic purposes. The bark commonly possesses tonic, astringent, and febrifugal properties. The hairs which invest the seeds have been employed for stuffing cushions, and for other purposes. The buds of some species secrete an oleo-resinous substance of a stimulating nature.

Order 43. LACISTEMACEÆ.—The Lacistema Order.—Character.—*Shrubs*. *Leaves* simple, alternate, dotted, stipulate. *Flowers* in axillary catkins, perfect or unisexual. *Calyx* inferior, with several divisions, enclosed by a bract. *Stamen* 1, hypogynous, with a 2-lobed connective, each lobe bearing 1 cell of the anther, which bursts transversely. *Ovary* superior, seated in a disc, 1-celled, with numerous ovules attached to parietal placentas. *Fruit* capsular, 1-celled, 2—3-valved *Seeds* generally 2 or 3, arillate, suspended, with fleshy albumen.

Distribution, Numbers, and Properties.—Natives of woody places in tropical America. *Illustrative Genera*:—There are 2 genera, namely, Lacistema, *Swartz*, and Synzyganthera, *R.*

et P., which contain 6 species. Their properties and uses are unknown.

Order 44. EMPETRACEÆ, the Crowberry Order.—Character.—Small heath-like evergreen *shrubs*. *Leaves* exstipulate. *Flowers* axillary, small, unisexual. *Calyx* of 4—6 persistent, imbricate, hypogynous scales, the innermost occasionally petaloid and combined. *Stamens* alternate with, and equal in number to, the inner sepals or scales. *Ovary* superior, placed on a disc, 2—9-celled; *ovules* solitary. *Fruit* fleshy, composed of from 2 to 9 nuts. *Seed* solitary in each nut, ascending; *embryo* with an inferior radicle in fleshy-watery albumen.

Distribution and Numbers.—Mostly natives of Northern Europe and North America. *Illustrative Genera:*—Empetrum, *Linn.*; Corema, *Don.* There are 4 species.

Properties and Uses.—The leaves and fruit are generally slightly acid. The berries of *Empetrum nigrum*, the Crowberry, are eaten in the very cold parts of Europe, and are also employed in Greenland in the preparation of a fermented liquor. In Portugal, the berries of *Corema* are used in the preparation of a beverage which is said to be useful in febrile complaints.

Order 45. CERATOPHYLLACEÆ, the Hornwort Order.—Character.—Aquatic *herbs*. *Leaves* verticillate, very finely divided. *Flowers* minute, axillary, sessile, monœcious. *Calyx* or rather *perianth* inferior, 8—12-partite. *Male flower* consisting of 12—20 *stamens*; *anthers* sessile, 2-celled. *Female flower* with a superior 1-celled *ovary*, and 1 pendulous orthotropous *ovule*. *Fruit* hard or nut-like, indehiscent. *Seed* exalbuminous, pendulous; *embryo* with a large many-leaved plumule, and a very short inferior radicle.

Distribution and Properties.—Natives of the northern hemisphere. *Ceratophyllum*, Linn., is the only genus. The properties and uses of the species are unknown.

Artificial Analysis of the Orders in the Sub-class.

MONOCHLAMYDEÆ or INCOMPLETÆ.

(*Modified from Lindley.*)

1. Achlamydeous Flowers.

A. Leaves stipulate.

a. *Flowers unisexual.*

Ovary 1-celled.

Ovules numerous . . . . . *Salicaceæ.*

Ovules 1—2.
Ovule erect . . . . *Myricaceæ.*
Ovule pendulous . . . . . . *Platanaceæ.*
Ovary 2- or more-celled.
Seeds few, not winged . . . . . *Euphorbiaceæ.*

b. *Flowers hermaphrodite.*
Carpel solitary.
Ovule erect. Embryo with endosperm and perisperm . . . . *Piperaceæ*
Ovule suspended. Embryo with endosperm *Chloranthaceæ.*
Carpels several.
Ovule erect. Embryo with endosperm . *Sauruaceæ.*

B. Leaves exstipulate.

a. *Flowers unisexual.*
Ovules very numerous . . . . *Podostemaceæ.*
Ovules solitary or very few.
Flowers naked.
Ovary 1-celled . . . . . . *Myricaceæ.*
Flowers within an involucre.
Anther-valves recurved . . . . *Atherospermaceæ.*
Anther-valves slit.
Embryo on the outside of the albumen . *Monimiaceæ.*
Embryo enclosed in the albumen . . *Euphorbiaceæ.*

b. *Flowers hermaphrodite.*
Embryo with endosperm . . . *Piperaceæ.*
Embryo without endosperm . . . . *Podostemaceæ.*

2. Monochlamydeous Flowers.

A. Ovary inferior, or partially so.

a. *Leaves stipulate.*
1. Flowers hermaphrodite . . . . . *Aristolochiaceæ.*
2. Flowers unisexual . . . . *Corylaceæ.*

b. *Leaves exstipulate.*
1. Flowers hermaphrodite.
Ovary 3—6-celled. Ovules numerous . *Aristolochiaceæ.*
Ovary 1-celled. Ovules definite.
Ovules with a naked nucellus. Leaves opposite . . . . *Loranthaceæ.*
Ovules with a naked nucellus. Leaves alternate . . . . *Santalaceæ.*
Ovules with integuments . . . . *Chenopodiaceæ.*
2. Flowers unisexual.
Amentaceous . . . . *Juglandaceæ.*

B. Ovary superior.

a. *Leaves stipulate.*
1. Flowers hermaphrodite.
a. Carpel solitary.
Stipules ochreate . . . . . . *Polygonaceæ.*
Stipules distinct . . . . . . *Petiveriaceæ.*

b. Carpels more than one, combined.
Seeds exalbuminous.
Calyx imbricate . . . . . *Ulmaceæ.*
Seeds albuminous.
Styles or stigmas 2. Leaves not dotted *Ulmaceæ.*

2. Flowers unisexual.

a. Carpel solitary.
Cells of anther perpendicular to the filament . . . . . . *Stilaginaceæ.*
Cells of anther parallel to the filament.
Embryo straight.
Sap watery. Stipules small. Seeds albuminous . . . . . *Urticaceæ.*
Sap milky. Stipules large. Seeds exalbuminous . . . . . *Artocarpaceæ.*
Embryo hooked.
Sap watery. Seeds without albumen *Cannabinaceæ*
Sap milky. Seeds with albumen . *Moraceæ.*

b. Carpels more than one, combined.
Flowers amentaceous.
Seeds arillate.
Stamen 1 . . . . . *Lacistemaceæ*
Stamens more than 1 . . . *Scepaceæ.*
Seeds not arillate . . . *Betulaceæ.*
Flowers not amentaceous . . *Euphorbiaceæ*

b. *Leaves exstipulate.*

1. Flowers hermaphrodite.

a. Carpel solitary.
Anther-valves recurved . . . . *Lauraceæ.*
Anthers slit.
Leaves covered with scales . . . *Elæagnaceæ.*
Leaves not so covered.
Calyx long or tubular.
Hardened at base . . . . *Nyctaginaceæ.*
Not hardened in any part.
Stamens in the points of the sepals *Proteaceæ.*
Stamens not in the points of the sepals . . . . . *Thymelaceæ.*
Calyx short, not tubular, or but slightly so.
Flowers in involucels . . . *Polygonaceæ.*
Flowers not in involucels.
Calyx dry and coloured . . *Amarantaceæ.*
Calyx herbaceous or succulent.
Stamens hypogynous or nearly so . . . . . . *Chenopodiaceæ*
Stamens perigynous . . . *Basellaceæ.*

b. Carpels more than one, either distinct or combined.
Carpels distinct . . . . . *Phytolaccaceæ.*
Carpels combined.
Seeds exalbuminous.
Calyx tubular.
Ovary 2-celled . . . . . *Aquilariaceæ.*
Ovary 4-celled . . . . . *Penæaceæ.*
Calyx tubular, or imperfect . . *Podostemaceæ.*
Seeds albuminous . . . . . *Phytolaccaceæ.*

2. Flowers unisexual.
a. Carpels solitary, or quite distinct.
Calyx tubular.
Anthers opening by recurved valves . *Atherospermaceæ.*
Anthers opening longitudinally . . *Myristicaceæ.*
Calyx not tubular.
Seeds exalbuminous. Embryo straight.
Leaves verticillate . . . . *Ceratophyllaceæ*
No evident leaves . . . . *Casuarinaceæ.*
Seeds albuminous.
Embryo curled round the albumen . *Chenopodiaceæ.*
Embryo straight . . . . . *Monimiaceæ.*
b. Carpels more than one, combined.
Ovules indefinite.
Leaves with pitchers . . . . *Nepenthaceæ.*
Ovules definite.
Fruit fleshy. Seeds ascending . . *Empetraceæ.*
Fruit dry. Seeds suspended . . . *Euphorbiaceæ.*

Root Parasites (Rhizogens of Lindley).

A. Ovary inferior. Ovules solitary . . . . *Balanophoraceæ.*

B. Ovary superior. Ovules indefinite.
Anthers opening longitudinally . . . *Cytinaceæ.*
Anthers opening by pores . . . . . *Rafflesiaceæ.*

Monochlamydeous or Achlamydeous flowers also occasionally, or in some orders always, occur in plants belonging to the following orders of the Sub-classes Polypetalæ and Gamopetalæ :—

Sub-class 1. Polypetalæ :—

Series 1. Thalamifloræ :—*Ranunculaceæ*, *Menispermaceæ*, *Papaveraceæ*, *Bixaceæ*, *Caryophyllaceæ*, *Scleranthaceæ*, *Paronychiaceæ*, *Sterculiaceæ*, *Byttneriaceæ*, *Tiliaceæ*.

Series 2. Discifloræ :—*Malpighiaceæ*, *Rutaceæ*, *Chailletiaceæ*, *Xanthoxylaceæ*, *Geraniaceæ*, *Celastraceæ*, *Rhamnaceæ*, and *Anacardiaceæ*.

Series 3. Calycifloræ :—*Leguminosæ*, *Rosaceæ*, *Lythraceæ*,

Saxifragaceæ, *Cunoniaceæ*, *Begoniaceæ*, *Datiscaceæ*, *Mesembryanthaceæ*, *Passifloraceæ*, *Myrtaceæ*, *Onagraceæ*, *Samydaceæ*, *Haloragaceæ*, *Combretaceæ*, *Hamamelidaceæ*, and *Araliaceæ*.

Sub-class 2. Gamopetalæ :—*Oleaceæ* and *Primulaceæ*.

Synopsis of the British Natural Orders of the Sub-class Monochlamydeæ.

A. Male flowers in catkins.
  Flowers diœcious.
    Male and female flowers in catkins.
      Fruit dry . . . . *Salicaceæ.*
      Fruit drupaceous . . . . . . *Myricaceæ.*
  Flowers monœcious.
    Flowers all in catkins . . . . . . *Betulaceæ.*
    Male flowers only in catkins . . . . *Cupuliferæ.*

B. Flowers not in catkins.
  Ovary inferior. Fruit indehiscent.
      Stamens 4—5, epiphyllous . . . . *Santalaceæ.*
      Stamens 6—12, epigynous . . . . *Aristolochiaceæ.*
  Ovary one, superior. Perianth sometimes absent.
    Fruit separating into several carpels. No perianth . . . . *Euphorbiaceæ.*
    Fruit not separating into carpels.
      Leaves stipulate.
        Stipules ochreate . . . . . *Polygonaceæ.*
        Stipules free deciduous. Ovary 1-celled.
          Perianth 4—5-parted . . . . *Urticaceæ.*
          Perianth of female flower scale-like, open *Cannabinaceæ.*
        Stipules free deciduous. Ovary 2-celled . *Ulmaceæ.*
      Leaves exstipulate.
        Flowers monœcious or diœcious.
          Fruit fleshy. Stamens 2 or 3. Perianth scaly, imbricated . . . . . *Empetraceæ.*
          Fruit dry.
            Stamens 3 or more. Perianth tubular *Elæagnaceæ.*
            Stamens 12–20. Perianth 10–12-cleft *Ceratophyllaceæ.*
        Flowers perfect or polygamous.
          Perianth 3–5-cleft, herbaceous. Fruit a utricle . . . . *Chenopodiaceæ.*
          Perianth 3-cleft, scarious . . . *Amaranthaceæ.*
          Perianth tubular. Stamens perigynous *Thymelaceæ.*

Sub-Class II.—Polypetalæ.

Series I.—*Thalamifloræ.*

Cohort 1.—*Ranales.*

Order 46. Ranunculaceæ, the Buttercup Order.—Character.—Herbs or rarely climbing shrubs, with a watery, colourless, usually acrid juice. *Leaves* radical or alternate (or opposite in Clematideæ), generally much divided, or sometimes entire, with usually dilated and amplexicaul petioles. *Stipules*

Fig. 1019.

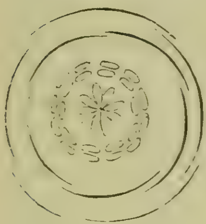


Fig. 1020.

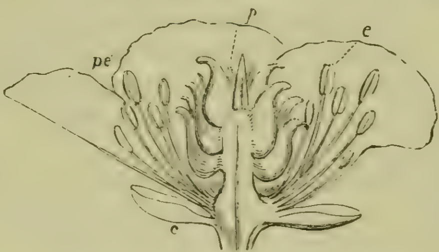


Fig. 1021.

Fig. 1022.

Fig. 1023.

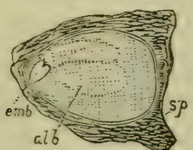


Fig. 1024.

Fig. 1019. Diagram of the flower of a species of *Ranunculus.*——*Fig.* 1020. Vertical section of the flower of *Ranunculus acris.* *c.* Calyx. *pe.* Petals. *e.* Stamens. *p.* Carpels.——*Fig.* 1021. Adnate anther of a Ranunculaceous plant.——*Fig.* 1022. Numerous follicles of *Trollius europæus.*——*Fig.* 1023. Vertical section of the seed of the Monkshood (*Aconitum*). *sp.* Coverings of the seed. *emb.* Embryo. *alb.* Albumen.——*Fig.* 1024. Vertical section of a carpel of *Ranunculus acris.* *o.* Ovary. *g.* Ovule. *s.* Stigma.

generally absent; if present, adnate. *Inflorescence* generally terminal; one-flowered, or racemose, or paniculate. *Flowers* regular, or rarely irregular, usually hermaphrodite; often acyclic or hemicyclic. *Calyx* of 3-6, usually 5 distinct sepals, regular or irregular, sometimes petaloid; deciduous, or very rarely persistent; æstivation imbricate (or valvate in Clematideæ). *Corolla* either isomerous with the calyx, or having numerous petals; regular or irregular. *Petals* distinct, hypogynous, sometimes 0; sometimes modified into nectaries: æstivation imbricate. *Stamens* ∞, pluriseriate, or spirally ar-

ranged; hypogynous, free; anthers innate, dehiscing longitudinally. *Carpels* ∞, or rarely few or only one; usually distinct and one-celled; rarely forming a compound ovary; when numerous, spirally arranged. *Ovary* with one or many ovules. *Ovules* anatropous. *Fruit* generally consisting of a number of achenes; sometimes of several follicles; very rarely baccate or capsular. *Seeds* solitary or numerous; when solitary, erect or pendulous; exarillate. *Embryo* minute, embedded in horny or rarely fleshy albumen.

Diagnosis.—Herbs or rarely shrubs, with a colourless, watery, and usually acrid juice. Sepals, petals, and stamens distinct, hypogynous. Corolla with an imbricate æstivation. Stamens usually numerous; anthers adnate, bursting longitudinally. Carpels, except in a very few instances, more or less distinct. Seeds with a minute embryo, and homogeneous horny albumen, anatropous.

Ranunculaceæ may be distinguished from Papaveraceæ by the apocarpous pistil and watery juice; from Berberidaceæ by the herbaceous habit, the indefinite stamens, and the dehiscence of the anthers; from Dilleniaceæ by the habit, the deciduous sepals, and the absence of an aril to the seeds; from Magnoliaceæ by the habit and by the arrangement of the perianth.

The order is divided into the following tribes:—

Tribe 1. *Clematideæ.*—Sepals usually valvate. Petals absent. Carpels with one ovule, which is pendulous. Fruit consisting of a number of achenes. Stem herbaceous or climbing; leaves opposite.

Tribe 2. *Anemoneæ.*—Sepals imbricate. Carpels with a single pendulous ovule. Fruit consisting of a number of achenes. Leaves radical, or alternate; sometimes simulating an involucre.

Tribe 3. *Ranunculeæ.*—Sepals imbricate. Carpels with a single ascending ovule. Fruit a number of achenes. Leaves radical or alternate.

Tribe 4. *Helleboreæ.*—Flowers regular or irregular. Sepals imbricate. Petals small, or irregular, or absent. Fruit a number of follicles, or rarely a capsule or a berry.

Tribe 5. *Pæonieæ.*—Sepals imbricate. Fruit of 2–5 follicles, more or less surrounded at the base by a cup-shaped disc.

Distribution.—The order includes 30 genera and about 600 species. It is widespread in its distribution, but is scantily represented in the tropics, except on mountains.

Properties and Uses.—The plants of this order generally abound in an acrid principle, which in some is even vesicant. This acridity is, however, very volatile, so that in most cases it is dissipated by drying, or by infusing them in boiling, or even sometimes in cold water; it varies also in different parts of the same plant, and even in the same parts at different seasons. Some plants contain in addition a narcotic principle; and when these principles are in excess, they are virulent poisons. Generally the plants of this order are to be regarded with suspicion, although some are simply bitter and tonic.

Order 47. DILLENIACEÆ, the Dillenia Order.—Character.—*Trees* or *shrubs*, sometimes climbing; rarely *herbs*. *Leaves* alternate, entire or dentate, rarely pinnatifid or trifid; generally exstipulate. *Sepals* 5, rarely 3-4 or ∞, persistent. *Petals* 5 or fewer, hypogynous, imbricate, free. *Stamens* ∞, rarely definite, 10 or fewer, hypogynous, free, or united at their bases. *Carpels* 1–∞, generally free. *Ovules* 1– , anatropous. *Seeds* 1 or few, arillate. *Embryo* minute in fleshy albumen.

Diagnosis.—Stipules absent, except in rare cases. Sepals and petals 5 each, hypogynous; the former persistent in two rows, the latter with an imbricate æstivation. Carpels more or less distinct. Seeds numerous, arillate; albumen fleshy, homogeneous.

Dilleniaceæ differ from Ranunculaceæ in habit, and in their having a persistent calyx and arillate seeds; from Magnoliaceæ in the latter possessing a multiseriate perianth.

Distribution and Numbers.—The plants of this order occur chiefly in Australia, India, and equinoctial America; a few species have been also found in equinoctial Africa; none occur in Europe. *Illustrative Genera*:—Dillenia, *Linn.*; Candollea, *Labill.* There are 17 genera and nearly 200 species belonging to this order.

Properties and Uses.—These plants have generally astringent properties; they have been used as vulneraries, and for tanning in Brazil.

Order 48. CALYCANTHACEÆ, the Calycanthus Order.—Character.—*Shrubs* with opposite entire exstipulate leaves. *Sepals* and *petals* arranged in several series, inserted on a hollow urceolate receptacle. *Stamens* ∞, closing the throat of the receptacle; inner ones sterile. *Carpels* ∞, free; situated in the cavity of the hollow receptacle. *Ovules* solitary or two together, anatropous. *Fruit* a number of achenes. *Seeds* erect, exalbuminous. *Cotyledons* foliaceous, convolute.

Distribution and Numbers.—They are natives of Japan and North America. *Illustrative Genera:*—Calycanthus, Chimonanthus. These are the only 2 genera, which include 4 species.

Properties and Uses.—The flowers generally are fragrant and aromatic; and the bark of *Calycanthus floridus*, Carolina Allspice, is sometimes used in the United States as a substitute for Cinnamon bark.

Order 49. MAGNOLIACEÆ, the Magnolia Order.—Character.—*Trees* or *shrubs*, frequently aromatic. *Leaves* alternate, usually entire; often with convolute stipules, which enclose the buds and fall off as the latter open. *Flowers* axillary or terminal, rarely racemose or fascicled; sometimes unisexual. *Sepals* and *petals* multiseriate, usually in whorls of 3; imbricate, deciduous. *Stamens* ∞, arranged spirally, hypogynous, free; *anthers* adnate. *Carpels* ∞, or rarely solitary or few, free or rarely coherent; sometimes multiseriate or spirally arranged in a head or spike. *Ovules* 2—∞, anatropous, pendulous, or rarely erect. *Fruit* capsular, or indehiscent and fleshy, or a samara. *Seeds* with a fleshy or crustaceous testa; *embryo* minute, in a copious oily or fleshy albumen, which is not ruminated.

Diagnosis.—Trees or shrubs. Leaves alternate, leathery. Stipules usually present, and then large and enveloping the leaf-bud; deciduous. Sepals and petals with a ternary arrangement of their parts, hypogynous, the former deciduous, the latter with an imbricate æstivation. Carpels distinct or coherent at the base. Albumen homogeneous.

The order is divided into the following tribes:—

Tribe 1. *Trochodendreæ.*—Sepals and petals 0. Flowers polygamo-diœcious. Carpels whorled, uniseriate. Stipules 0.

Tribe 2. *Wintereæ.*—Flowers hermaphrodite or polygamous. Carpels whorled, uniseriate, or solitary. Stipules 0.

Tribe 3. *Magnolieæ.*—Flowers hermaphrodite. Carpels imbricate, multiseriate, on an elongated thalamus. Stipules enclosing the leaves.

Tribe 4. *Schizandreæ.*—Flowers unisexual. Fruit baccate. Carpels as in Tribe 3. Stipules 0.

Distribution.—The order includes 9 genera and 70 species; it flourishes in tropical and eastern Asia and in North America; it is sparingly represented in tropical and extra-tropical South America, and in Australia and New Zealand. No plants of the order occur in Europe or Africa. Magnoliaceæ are distinguished from Dilleniaceæ by the absence of an aril from the seeds, and from Anonaceæ by the non-ruminated albumen.

Properties and Uses.—These plants are chiefly remarkable for bitter, tonic, and aromatic principles. Some of the Schizandreæ have mucilaginous edible fruits.

Order 50. ANONACEÆ, the Custard-apple Order.—Character.—*Trees* or *shrubs*, sometimes climbing. *Leaves* alternate, simple, exstipulate. *Calyx* of three sepals, generally united at the base, persistent. *Corolla* of usually six petals, in two whorls, leathery; *æstivation* usually valvate; hypogynous, rarely united. *Stamens* usually numerous, and inserted on a large hypogynous thalamus; *connective* enlarged, 4-angled; *anthers* adnate. *Carpels* usually numerous, distinct or united, or very rarely solitary, with one or more anatropous *ovules*. *Fruit* composed of a number of dry or succulent carpels, which are distinct, or united so as to form a fleshy mass; or rarely simple. *Seeds* one or more, anatropous; *embryo* minute; *albumen* ruminated.

Diagnosis.—Trees or shrubs. Leaves alternate. No stipules. Calyx of 3 sepals, persistent. Petals 6, in two rows, hypogynous, usually valvate. Anthers adnate, with an enlarged 4-cornered connective. Albumen ruminated.

Distribution and Numbers.—The plants of this order are almost entirely confined to the tropical regions of Asia, Africa, and America. None are found in Europe. *Illustrative Genera*:—Xylopia, *Linn.*; Anona, *Linn.*; Monodora, *Dunal.* There are 47 genera and nearly 400 species in this order.

Properties and Uses.—Generally aromatic and fragrant in all their parts. Some have edible fruits, which are much esteemed.

Order 51. MENISPERMACEÆ, the Moon-seed Order.—Character.—Climbing or trailing *shrubs*. *Leaves* alternate, simple, exstipulate, usually entire. *Flowers* diœcious. *Staminate flower*:—*Calyx* and *corolla* with a ternary arrangement of their parts, generally in two whorls, imbricate or valvate. *Stamens* usually distinct, equal and opposite to the petals, rarely more or fewer, sometimes monadelphous. *Carpels* rudimentary or wanting. *Pistillate flower*:—*Sepals* and *petals* usually resembling those of the ♂ flower. *Stamens* imperfectly developed, or wanting. *Carpels* usually 3, sometimes 6 or ∞, commonly supported on a gynophore, distinct, 1-celled, each containing one curved ovule. *Fruits* drupaceous, curved around a central placental process, 1-celled. *Seeds* 1 in each cell, and curved so as to assume the form of that cell; *embryo* curved; *albumen* copious or scanty; sometimes ruminate; rarely 0.

Diagnosis.—Trailing or climbing shrubs. Leaves alternate,

simple, exstipulate. Flowers usually diœcious. Sepals, petals, stamens, and carpels with a ternary arrangement, hypogynous. Carpels distinct. Fruits 1-celled, curved. Seed solitary, curved; embryo curved; albumen absent, or usually small in amount, and then either homogeneous or somewhat ruminated.

Distribution and Numbers.—The plants of this order are chiefly found in the forests of the tropical parts of Asia and America. None occur in Europe. *Illustrative Genera:*—Jateorhiza, *Miers*; Menispermum, *Tourn.* There are 38 genera and fewer than 100 species included in this order.

Properties and Uses.—These plants are chiefly remarkable for their narcotic and bitter properties. A few are mucilaginous. When the narcotic principle is in excess they are very poisonous. Some are valuable tonics.

Order 52. BERBERIDACEÆ, the Barberry Order.—Character.—*Herbs, undershrubs* or *shrubs*, often climbing (in Lardizabaleæ). *Leaves* alternate or radical, sometimes simple, sometimes pinnate or palmate, sometimes reduced to spines, usually exstipulate. *Flowers* regular, hermaphrodite, or unisexual, solitary axillary, or in spikes, racemes, panicles, or cymes. *Sepals* deciduous, in 1—∞ whorls of 2 or 3 each, often petaloid; *petals* equal in number to the sepals and opposite to them, or twice as many, hypogynous. *Stamens* in 1—3 series, opposite to the petals, generally free, but monadelphous in some Lardizabaleæ; hypogynous. *Anthers* dehiscing longitudinally or by recurved valves. *Carpels* 1 or 3, distinct; *ovules* anatropous, attached to a marginal placenta, or scattered over the surface of the ovary wall. *Fruit* baccate, or dry and follicular; *seeds* albuminous.

The order is divided into two tribes as follows:—

Tribe 1. *Lardizabaleæ.* Flowers unisexual, anthers dehiscing longitudinally, carpels 3.

Tribe 2. *Berbereæ.* Flowers hermaphrodite; anthers dehiscing by recurved valves (except in *Podophyllum* and *Nandina*), carpel solitary.

Diagnosis.—Leaves alternate, very often spiny. Sepals 3, 4, 6, or ∞, deciduous. Petals hypogynous, and opposite to the sepals when equal to them in number. Stamens definite, hypogynous, opposite to the petals; anthers 2-celled, each opening by a recurved valve, except in Tribe 1 and the genera *Podophyllum* and *Nandina*, where they dehisce longitudinally. Carpel solitary; placenta marginal; ovules anatropous. Seeds with albumen.

Distribution and Numbers.—They are found in the temperate parts of Europe, America, and Asia, and are very common in the mountainous parts of the North of India. *Illustrative Genera* :—Berberis, *Linn.*; Epimedium, *Linn.*; Leontice, *Linn.* The order includes 20 genera and about 100 species.

Properties and Uses.—These plants are generally acid, astringent, and bitter; but some are purgative. Their acid properties are due to the presence of oxalic acid.

Order 53. NYMPHÆACEÆ, the Water-lily Order.—Character.—*Aquatic herbs*, with generally floating leaves which are peltate or cordate; when submerged leaves are present, they are much divided. *Flowers* generally floating, sometimes emerged,

FIG. 1025.

FIG. 1026.

FIG. 1027.

FIG. 1028.

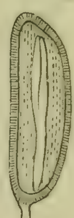


Fig. 1025. Diagram of the flower of the Barberry (*Berberis*).——*Fig.* 1026. Vertical section of the flower of *Epimedium*.——*Fig.* 1027. Vertical section of the ovary of *Berberis*.——*Fig.* 1028. Vertical section of the seed of *Berberis*, with the embryo in the axis surrounded by albumen.

solitary, large and showy; usually acyclic, without any sharp demarcation between the petals and stamens. *Sepals* 3—5, *petals* 3—∞, imbricate; *stamens* 6—∞: outer filaments petaloid. The petals and stamens are sometimes all free and hypogynous, sometimes all, or the inner ones only, inserted at different heights on a torus which encloses the carpels. *Carpels* 3—8, sometimes distinct, but usually cohering in a whorl and forming a many-celled ovary, which is free and superior in *Nuphar* or adherent to the torus in *Nymphæa* and other genera. Sometimes the carpels are embedded singly in cavities in the

flattened torus (*Nelumbium*). *Stigmas* either distinct or uniting into an epigynous disc. *Ovules* anatropous, or in *Barclaya* orthotropous, distributed over the surface of the dissepiments of the ovary, or pendulous from the central suture or the apex of the carpels when the latter are distinct. *Seeds* albuminous, with endosperm and perisperm, or exalbuminous; arillate or naked.

The order is divided into the following sub-orders:—

Sub-order 1. *Cabombeæ.*—Sepals and petals 3. Carpels 3. Ovules few. Flowers small.

Sub-order 2. *Nymphææ.*—Sepals 4—6. Petals and stamens ∞. Carpels numerous, coherent. Ovules ∞. Flowers generally showy.

Sub-order 3. *Nelumboneæ.*—Sepals 4—5. Petals and stamens ∞. Carpels sunk in a fleshy torus. Ovules 1—2. Seeds exalbuminous.

Distribution.—The plants of this order are chiefly found in

FIG. 1029.

FIG. 1030.

FIG. 1031.

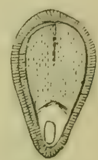


Fig. 1029. Flower of Yellow Water-lily (*Nuphar luteum*).——*Fig.* 1030. Ovary of *Nuphar* with numerous radiating stigmas.——*Fig.* 1031. Vertical section of the seed of *Nymphæa alba*, showing the embryo embedded in endosperm, outside which lies a mass of perisperm.

quiet waters throughout the whole of the northern hemisphere and more sparingly in the southern. *Illustrative Genera*:—Victoria, *Lindl.*; Nymphæa, *Linn.*; Cabomba, *Aubl.*; Nelumbium. There are 8 genera and 35 species.

This order is distinguished from the others of the Ranales by the seeds usually containing both endosperm and perisperm. The Nymphææ approach the Papaveraceæ in their placentation, but differ in the contents of the seed, and in their habit. The character of the seeds is almost the only distinction between Cabomba and the Ranunculaceæ.

Properties and Uses.—These plants have bitter and astringent properties. The flowers are said to be narcotic.

Cohort 2.—*Parietales.*

Order 54. SARRACENIACEÆ, the Side-saddle-flower Order.—Character.—*Perennial herbs*, growing in boggy places, with radical hollow leaves, which are pitcher- or trumpet-shaped. *Sepals* 4—6, usually 5, persistent, imbricate. *Petals* 5, hypogynous, sometimes absent. *Stamens* numerous, hypogynous; *anthers* adnate, 2-celled. *Carpels* 3—5, united so as to form a compound 3—5-celled ovary; *ovules* numerous; *placentas* axile; *style* simple and truncate, or expanded at its top into a large shield-like angular process with one stigma beneath each of its angles. *Capsule* 3—5-celled dehiscing loculicidally. *Seeds*

FIG. 1032.

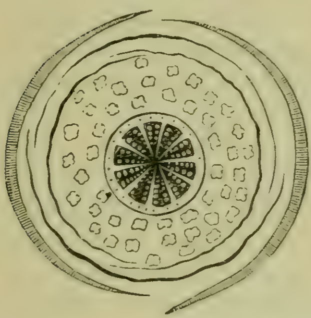


FIG. 1033.

FIG. 1034.

Fig. 1032. Diagram of the flower of the Poppy, with two sepals, four crumpled petals, numerous stamens, and a compound one-celled ovary with several parietal placentas projecting into its interior so as to nearly divide it into several cells.——*Fig.* 1033. Flower of Celandine (*Chelidonium majus*). *sti.* Two stigmas on the apex of a lengthened or pod-like ovary.——*Fig.* 1034. Siliquæform or pod-shaped capsule (*ceratium*) of Celandine.

numerous, attached to large axile placentas; *albumen* abundant.

Diagnosis.—Perennial boggy plants, with pitcher- or trumpet-shaped leaves. Calyx permanent, imbricate. Carpels united so as to form a compound ovary and a 3—5-celled dehiscing fruit, with large axile placentas; albumen abundant.

Distribution and Numbers.—There are 8 species, of which 6 are confined to the bogs of North America; 1 occurs in Guiana, the other species is found in California. *Illustrative Genera*:—Sarracenia, Heliamphora.

Properties and Uses.—The pitchers serve to entrap any insects that find their way into them. They contain a watery fluid in which the insects drown and putrefy, and the solution

thus formed is ultimately absorbed, and appears to be necessary for the healthy condition of the plants.

Order 55. PAPAVERACEÆ, the Poppy Order.—Character.—*Herbs* or *shrubs*, usually with a milky juice (white or coloured). *Leaves* alternate, exstipulate. *Sepals* usually 2 or rarely 3, caducous. *Petals* 4 (*figs.* 1032 and 1033), or rarely 6, or some multiple of 4, or very rarely wanting; usually crumpled in æstivation, hypogynous. *Stamens* generally numerous and hypogynous; *anthers* 2-celled, innate. Ovary 1-celled, with 2 or more parietal placentas, which project more or less from the walls into its cavity, and in *Romneya* actually cohere in the axis; *styles* absent or very short; *stigmas* 2 or many, alternate with the placentas, and opposite the imperfect dissepiments; when numerous, they form a star-like process on the top of the ovary; *ovules* numerous. *Fruit* 1-celled, and either pod-shaped with 2 parietal placentas, or capsular with several placentas; dehiscing by valves or pores, or sometimes indehiscent. *Seeds* usually numerous; *embryo* in fleshy-oily albumen.

Diagnosis.—Usually herbs with a milky juice. Leaves alternate and exstipulate. Peduncles 1-flowered; flowers regular and symmetrical. Calyx and corolla with a binary or ternary arrangement of their parts, deciduous, hypogynous. Stamens numerous, generally hypogynous; anthers 2-celled, innate. Ovary compound, 1-celled, with parietal placentas, stigmas alternate to the placentas. Fruit 1-celled, except in *Romneya*. Seeds numerous, albuminous.

Distribution and Numbers.—Nearly two-thirds of the plants of this order are natives of Europe, and are mostly annuals. They are almost unknown in tropical regions, and are but sparingly distributed out of Europe in a wild condition. *Illustrative Genera*:—Papaver, *Linn.*; Chelidonium, *Linn.* The order includes above 130 species.

Properties and Uses.—The plants of this order are in almost all cases characterised by well-marked narcotic properties. Some are acrid, while others are purgative. From a medicinal point of view, this order must be regarded as the most important in the Vegetable Kingdom on account of its yielding Opium, undoubtedly the most valuable drug of the Materia Medica.

Order 56. FUMARIACEÆ, the Fumitory Order.—Character.—*Smooth herbs* with a watery juice. *Leaves* alternate, much divided, exstipulate. *Sepals* 2, deciduous. *Petals* 4, cruciate, very irregular, in two whorls; one or both of the outer petals being gibbous or spurred, and the two inner frequently united

at the apex. *Stamens* hypogynous, usually 6, diadelphous, the two bundles being opposite the outer petals, and containing an equal number of stamens, the middle stamen of each bundle having a 2-celled anther, the two outer with 1-celled anthers; in rare cases there are four stamens, which are then distinct and opposite the petals. *Ovary* superior, 1-celled, with parietal placentas; *style* short, or long and filiform; *stigma* obtuse or lobed; *ovules* amphitropous. *Fruit* indehiscent and 1- or 2-seeded, or 2-valved and dehiscent, or a succulent indehiscent pod-like fruit; in the two latter cases containing a number of seeds. *Seeds* shining, crested; *embryo* abaxial, minute; *albu-*

FIG. 1035.

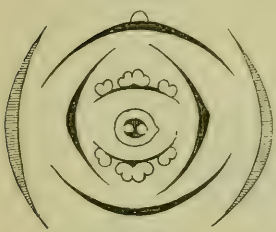


FIG. 1036.

FIG. 1037.

FIG. 1038.

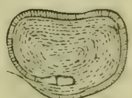


Fig. 1035. Diagram of the flower of *Corydalis*, with two sepals, four petals, in two whorls, six stamens in two bundles, and a one-celled ovary with two parietal placentas.——*Fig.* 1036. Vertical section of the flower of *Hypecoum*.——*Fig.* 1037. Upper or posterior petal of *Corydalis*, spurred at the base, and a bundle of three stamens.——*Fig.* 1038. Vertical section of the seed of *Fumaria*.

men fleshy. *This order is included in Papaveraceæ by Bentham and Hooker.*

Diagnosis.—Smooth herbs, with a watery juice, and alternate exstipulate much-divided leaves. Flowers very irregular and unsymmetrical, and either purple, white, or yellow. Sepals 2, deciduous. Stamens hypogynous, usually 6, diadelphous, or 4 distinct; always opposite to the petals. Ovary superior with parietal placentas; ovules amphitropous. Embryo minute, abaxial, in fleshy albumen.

Distribution and Numbers.—The plants of this order principally occur in thickets and waste places in the temperate latitudes of the northern hemisphere. *Illustrative Genera*:—Dicentra, *Borkh.*; Fumaria, *Tourn.* There are about 110 species.

Properties and Uses.—These plants possess slightly bitter, acrid, astringent, diaphoretic, emmenagogue, and aperient properties. The rhizomes or tubers of *Dicentra* (*Corydalis*) *formosa* are the source of *corydalin*, which is used by the eclectic practitioners in the United States of America in syphilis, scrofula, &c.; but the properties of this and other plants of the order appear to be unimportant. Some species are cultivated in our gardens and greenhouses. The most important of these is *Dicentra* (*Dielytra*) *spectabilis*, which has very showy flowers, but, like all other plants of the order, it is scentless.

Order 57. CRUCIFERÆ, the Cruciferous Order.—Character.—*Herbs*, or very rarely shrubby plants. *Leaves* alternate, exstipulate. *Flowers* usually yellow or white, rarely purple, or

FIG. 1039.

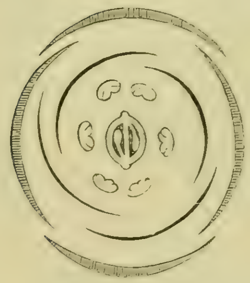


FIG. 1040.

Fig. 1039. Diagram of a Cruciferous flower.——*Fig.* 1040. Portion of the flowering branch of the Wallflower.

some mixture of these colours; *inflorescence* racemose or corymbose; usually ebracteate. *Sepals* 4, deciduous; *æstivation* imbricate or rarely valvate. *Petals* 4, hypogynous, arranged in the form of a Maltese cross, alternate with the sepals, deciduous. *Stamens* 6, tetradynamous, hypogynous. *Thalamus* furnished with small green glands placed between the stamens. *Ovary* superior, with two parietal placentas, 1-celled, or more usually 2-celled from the formation of a spurious dissepiment called the *replum*; *ovules* generally numerous, arranged alternately on two parietal placentas so as to form a single row, amphitropous or campylotropous; *style* none, or very short; *stigmas* 2, opposite the placentas. *Fruit* a siliqua or silicula, 1- or 2-celled, 1- or many-seeded. *Seeds*

stalked, generally pendulous ; *embryo* with the radicle variously folded upon the cotyledons ; *albumen* none, or very scanty.

Diagnosis.—Generally ebracteate herbs. Inflorescence indefinite; racemose or corymbose. Sepals and petals 4, deciduous, regular, the latter cruciate. Stamens tetradynamous. Ovary with two parietal placentas; stigmas 2. Fruit a siliqua or silicula. Seeds stalked, with the radicle variously folded upon the cotyledons. *No other order is likely to be confounded with this if ordinary care be taken, as tetradynamous stamens only occur here, except in a very few plants belonging to the order Capparidaceæ.*

Division of the Order and Illustrative Genera.—This large and truly natural order has been divided into sub-orders according to the nature of the fruit, and also as to the mode in which the embryo is folded. The latter is the most natural arrangement.

The sub-orders founded on the nature of the fruit are as follows :—

Sub-order 1. *Siliquosæ.*—Fruit a siliqua, opening by valves longitudinally. *Illustrative Genera :*—Cheiranthus, *Linn.*; Brassica, *Linn.*

Sub-order 2. *Siliculosæ latiseptæ.*—Fruit a silicula opening by valves; the replum in its broader diameter. *Illustrative Genus :*—Cochlearia, *Linn.*

Sub-order 3. *Siliculosæ angustiseptæ.*—Fruit a silicula opening by valves; the replum in its narrower diameter. *Illustrative Genera :*—Capsella, *Mœnch*; Iberis, *Linn.*

Sub-order 4. *Nucumentaceæ.*—Fruit an indehiscent silicula; often 1-celled, owing to the absence of the replum. *Illustrative Genus :*—Isatis, *Linn.*

Sub-order 5. *Sepulatæ.*—The valves of the fruit opening longitudinally and bearing transverse septa in their interior. There are no examples among British plants.

Sub-order 6. *Lomentaceæ.*—Fruit a siliqua or silicula, dividing transversely into 1-seeded portions, the true siliqua sometimes barren; the beak placed above it containing one or two seeds. *Illustrative Genera :*—Cakile, *Gaert.*; Raphanus, *Linn.*

The arrangement of Bentham and Hooker is essentially the same as the above.

The sub-orders founded on the mode in which the embryo is folded are as follows :—

Sub-order 1. *Pleurorhizeæ* (○ =).—Cotyledons accumbent, flat; radicle lateral. *Illustrative Genera:*—Cheiranthus, *Linn.*; Arabis, *Linn.*

Sub-order 2. *Notorhizeæ* (○ ‖).—Cotyledons incumbent, flat;

FIG. 1041.

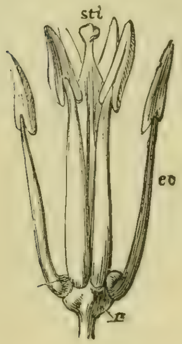


FIG. 1042.

FIG. 1043.

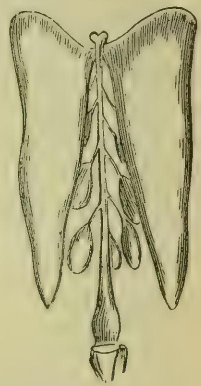


FIG. 1044.

FIG. 1045.

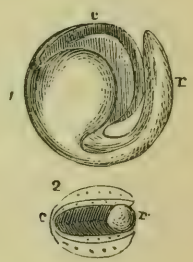


FIG. 1046.

Fig. 1041. Sporophylls of the Wallflower (*Cheiranthus Cheiri*). *r.* Thalamus. *gl.* Glands. *ec.* Tetradynamous stamens. *sti.* Stigmas.——*Fig.* 1042. An unripe siliqua of the Wallflower, with one of the valves removed to show the replum and the stalked pendulous seeds.——*Fig.* 1043. The silicula of Shepherd's Purse (*Capsella Bursa-pastoris*) in the act of dehiscing, showing the stalked pendulous seeds.——*Fig.* 1044. Silicula of the Scurvy-grass (*Cochlearia officinalis*) in the act of dehiscing.——*Fig.* 1045. The embryo of *Bunias orientalis.*——*Fig.* 1046. The embryo of the Cabbage plant (*Brassica oleracea*). 1. Undivided. 2. Horizontal section. *r.* Radicle. *c.* Cotyledons.

radicle dorsal. *Illustrative Genera:*—Hesperis, *Linn.*; Isatis, *Linn.*

Sub-order 3. *Orthoploceæ* (○ ≫).—Cotyledons conduplicate, longitudinally folded in the middle; radicle dorsal, within the fold. *Illustrative Genera:*—Brassica, *Linn.*; Raphanus, *Linn.*

Sub-order 4. *Spirolobeæ* (○ || ||).—Cotyledons twice folded, linear, incumbent. *Illustrative Genus:* — Bunias, *Linn.* There are no examples among British plants.

Sub-order 5. *Diplecolobeæ* (○ || || ||).—Cotyledons thrice folded, linear, incumbent. *Illustrative Genera:*—Senebiera, *DC.*; Subularia, *Linn.*

Distribution and Numbers.—The plants of this order chiefly inhabit temperate climates. A large number are also found in the frigid zone, and a few in tropical regions, chiefly on mountains. The order includes about 1,600 species.

Properties and Uses.—This order is generally characterised by antiscorbutic and pungent properties, frequently combined with acridity; it is one of the most natural in the Vegetable Kingdom, and does not contain a single poisonous plant. The seeds frequently contain a fixed oil. Many of our commonest culinary vegetables are derived from this order.

Order 58. CAPPARIDACEÆ, the Caper Order.—Character.—*Herbs, shrubs*, or rarely *trees. Leaves* alternate, exstipulate, or rarely with spiny stipulate appendages. *Sepals* 4, sometimes cohering more or less; *æstivation* imbricate or valvate, equal or unequal. *Petals* usually 4, cruciate, imbricate, generally unequal and unguiculate. rarely 8, or sometimes none. *Stamens* numerous or definite, if 6, very rarely tetradynamous, placed usually upon a prolonged thalamus or stalk by which they are raised above the calyx and corolla. *Ovary* placed on a gynophore or sessile, 1-celled; *placentas* 2 or more, parietal; *style* filiform or wanting; *ovules* amphitropous or campylotropous. *Fruit* 1-celled, usually many-seeded, very rarely 1-seeded, either pod-shaped and dehiscent, or baccate and indehiscent. *Seeds* generally reniform, without albumen; *embryo* curved; *cotyledons* leafy.

Diagnosis.—Herbs, shrubs, or trees, with alternate leaves. Sepals and petals 4 each, the latter cruciate, and generally unequal. Stamens usually numerous, very rarely tetradynamous, commonly inserted on a stalk, which raises them above the calyx and corolla. Ovary 1-celled, placentas parietal. Fruit dehiscent or indehiscent, 1-celled. Seeds generally reniform; embryo curved; no albumen.

Division of the Order and Illustrative Genera.—The order has been divided, according to the nature of the fruit, as follows:—

Sub-order 1. *Cleomeæ.*—Fruit capsular and dehiscent. *Illustrative Genera:*—Gynandropsis, *DC.*; Cleome, *DC.*

Sub-order 2.—*Cappareæ.*—Fruit baccate and indehiscent. *Illustrative Genera*:—Cadaba, *Forsk.*; Capparis, *Linn.*

Distribution and Numbers.—The plants of the order are found in tropical and subtropical regions of the globe. In Africa they are especially abundant. The common Caper (*Capparis spinosa*), which inhabits rocky places in the south of Europe, is the only European species, and also that one which is found farthest north. The order contains about 360 species.

Properties and Uses.—In their properties these plants resemble in many respects the Cruciferæ, being generally pungent, stimulant, and antiscorbutic. Others are aperient, diuretic, and anthelmintic. In some plants the pungent principle is highly concentrated, or probably is in itself deleterious, so that those in which it is found are very poisonous.

Order 59. RESEDACEÆ, the Mignonette Order.—Character.—*Herbs*, or rarely small *shrubs*. *Leaves* alternate, entire or divided, exstipulate, or with minute glandular stipules. *Calyx* with from 4 to 7 divisions. *Petals* 2—7, entire or with a deeply lobed or fringed limb, unequal. *Disc* fleshy, large, hypogynous, one-sided. *Stamens* definite, inserted on the disc. *Ovary* sessile, 1-celled; *ovules* amphitropous or campylotropous; *placentas* parietal; *stigmas* 3, sessile. *Fruit* usually opening at the apex long before the seeds are ripe, 1-celled. *Seeds* usually numerous, reniform; embryo curved, without albumen.

Diagnosis.—Usually herbs, with alternate leaves and unsymmetrical flowers. Disc large, hypogynous, one-sided. Stamens definite, not tetradynamous. Ovary sessile, 1-celled, with parietal placentation; stigmas 3, sessile. Fruit usually opening at the apex before the seeds are ripe. Seeds generally numerous, reniform, exalbuminous.

Distribution and Numbers.—They are chiefly natives of Europe and the adjoining parts of Africa and Asia. A few occur in the north of India, Cape of Good Hope, and California. *Illustrative Genera*:—Reseda, *Linn.*; Astrocarpus, *Neck.* There are about 45 species in this order.

Properties and Uses.—But little is known of their properties. The plants are generally somewhat acrid, and were formerly supposed to be sedative.

Order 60. CISTACEÆ, the Rock-rose Order.—Character.—*Shrubs* or *herbs*, often viscid. *Leaves* opposite or alternate, entire, stipulate or exstipulate. *Flowers* showy. *Sepals* usually 5, sometimes 3, persistent, unequal; *æstivation* of the three inner

twisted. *Petals* usually 5, very rarely 3, caducous, hypogynous, frequently corrugated in the bud, and twisted in a reverse way to that of the sepals. *Stamens* distinct, hypogynous, definite or indefinite. Ovary 1- or many-celled from parietal septa; *ovules* orthotropous; *style* single; *stigma* simple. *Fruit* capsular, usually 1-celled, with 3—5, or rarely 10 valves; or imperfectly 3—5—10-celled; *placentas* parietal. *Seeds* definite or numerous, albuminous; *embryo* curved or spiral, with the radicle remote from the hilum.

Diagnosis.—Leaves entire. Sepals and petals with a ternary or quinary arrangement, twisted in æstivation; the former persistent, the latter caducous. Stamens hypogynous, distinct. Ovary with parietal placentas and orthotropous ovules; style single; stigma simple. Fruit capsular. Seeds with mealy albumen; embryo inverted, curved or spiral.

Distribution and Numbers.—These plants are most abundant in the south of Europe and the north of Africa. Some few are

FIG. 1047.

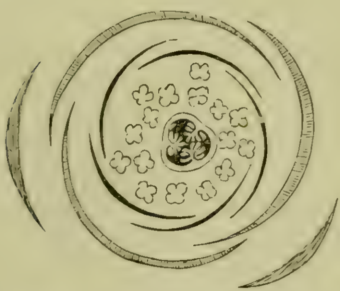


FIG. 1048.

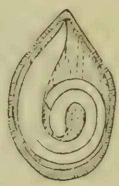


Fig. 1047. Diagram of the flower of a species of *Helianthemum*.——*Fig.* 1048. Section of the seed of a species of *Cistus*, the pointed end being its apex.

found in other parts of the globe. *Illustrative Genera*:—Cistus, *Tourn.*; Helianthemum, *Tourn.* There are about 200 species.

Properties and Uses.—These plants have generally resinous and balsamic properties. Some are regarded as stimulant, expectorant, and emmenagogue.

Order 61. VIOLACEÆ, the Violet Order.—Character.—*Herbs* or *shrubs*. *Leaves* simple, stipulate with an involute vernation, alternate or sometimes opposite. *Sepals* 5, persistent, imbricate, usually prolonged at the base. *Petals* 5, hypogynous, equal or unequal, one usually spurred. *Stamens* equal in number to the petals, and usually alternate with them,

or rarely opposite, inserted on a hypogynous disc, often unequal; *anthers* 2-celled, sometimes united, introrse; *filaments* short and broad, and elongated, so as to project beyond the anthers; when the flowers are irregular, two of the anthers are spurred at the base. *Ovary* 1-celled, with 3 parietal placentas; *style* single, usually declinate; *stigma* capitate oblique, hooded; *ovules* usually numerous. *Fruit* capsular, 3-valved, dehiscence loculicidal; *placentas* parietal, on the middle of the valves. *Seeds* usually numerous, sometimes definite; *embryo* straight, erect, in the axis of fleshy albumen.

Diagnosis.—Herbs or shrubs. Leaves simple, stipulate, and with involute vernation. Sepals, petals, and stamens 5 each, hypogynous. Stamens all perfect; anthers introrse with the filaments prolonged beyond them, and sometimes having spur-like appendages below. Ovary 1-celled, with three parietal placentas; style and stigma single. Fruit 1-celled, dehiscing by 3 valves, each valve bearing a placenta in its middle. Seeds having a straight erect embryo in the axis of fleshy albumen.

Fig. 1049.

Fig. 1050.

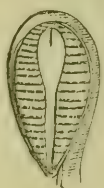


Fig. 1049. Sporophylls of the Pansy (*Viola tricolor*). *st.* Obliquely hooded stigma. *a.* United anthers, two having long spurred appendages at the base.——*Fig.* 1050. Vertical section of the seed.

Division of the Order and Illustrative Genera.—The order has been divided as follows:—

Sub-order 1. *Violeæ.*—Having irregular flowers and appendaged anthers. *Illustrative Genera:*—Viola, *Linn.*; Ionidium, *Vent.*

Sub-order 2. *Alsodeæ.*—With regular flowers, and anthers not furnished with spurred appendages. *Illustrative Genera:*—Alsodeia, *Thouars*; Pentaloba, *Lour.*

Distribution and Numbers. The herbaceous plants of the sub-order Violeæ are chiefly natives of Europe, Siberia, and North America; the shrubby mostly of South America. The

Alsodeæ are exclusively natives of South America, Africa, and Malacca. There are about 300 species belonging to the order.

Properties and Uses.—The plants of this order are chiefly remarkable for emetic and purgative properties. A few also are mucilaginous, and others have been reputed to be anodyne. The emetic property is due to a peculiar alkaloid named *violine*, which greatly resembles, if it be not identical with, *emetine*, the active principle of the true Ipecacuanha root. This principle is more especially found in some of the shrubby South American species, but it also occurs, to some extent at least, in many of the herbaceous European species.

Order 62. SAUVAGESIACEÆ, the Sauvagesia Order.—Character.—This order is by some botanists considered as merely a sub-order of Violaceæ. It is distinguished by the flowers of its species having either 5 perfect stamens alternate with 5 sterile ones, or numerous stamens. If there are only 5 stamens, these are also opposite the petals; the *anthers* are likewise extrorse, and have no appendages. The fruit also bursts septicidally, and hence each valve bears the placentas at its margins.

Distribution and Numbers.—They are natives chiefly of South America and the West Indies. *Illustrative Genera:*—Sauvagesia, *Linn.*; Lavradia, *Velloz.* There are about 15 species.

Properties and Uses.—But little is known of the properties of the plants in this order. *Sauvagesia erecta* contains a good deal of mucilaginous matter, and has been used internally as a diuretic, and in inflammation of the bowels, and also externally in diseases of the eye.

Order 63. CANELLACEÆ, the Canella Order.—*Diagnosis.*—By some authors this small order is placed in Clusiaceæ; it is, however, at once distinguished from the Clusiaceæ by its general appearance; alternate leaves; longitudinal dehiscence of anthers; absence of disc; presence of a style; and albuminous seeds. It is placed here in accordance with the views of Bentham and Hooker.

Distribution and Numbers.—This order contains but 2 genera and 3 species. They are natives of the West Indies and continent of America.

Properties and Uses.—These plants have aromatic, stimulant, and tonic properties; being closely allied in these respects to the Magnoliaceæ.

Order 64. BIXACEÆ, the Arnatto Order.—Character.—*Shrubs* or small *trees*. *Leaves* alternate, exstipulate, usually

entire and leathery, and very often dotted. Flowers polypetalous or apetalous; usually hermaphrodite, but sometimes unisexual. *Sepals* 4—7, somewhat united at the base. *Petals* hypogynous, distinct, equal in number to the sepals and alternate with them, or sometimes absent; sometimes with scales at the base. *Stamens* hypogynous, of the same number as the petals, or some multiple of them. *Ovary* 1- or more-celled, sessile or slightly stalked; *placentas* 2 or more, parietal, sometimes branched so as to form a network over the inner surface of the ovary and fruit. *Fruit* 1-celled, dehiscent or indehiscent, having a thin pulp in its centre. *Seeds* numerous, usually enveloped in a covering formed by the withered pulp; *albumen* fleshy-oily; *embryo* straight, axial; *radicle* turned to the hilum. The Pangiaceæ of some authors are included in this order, in accordance with the views of Bentham and Hooker.

Diagnosis.—Shrubs or small trees, with alternate exstipulate leaves. Flowers polypetalous or apetalous, rarely unisexual; petals hypogynous, sometimes with scales at the base. Stamens hypogynous, equal in number to the petals or some multiple of them. Fruit dehiscent or indehiscent; placentas parietal. Seeds numerous, albuminous; embryo axial, straight; radicle towards the hilum.

Distribution and Numbers.—The plants of this order are almost confined to the hottest parts of the East and West Indies, and Africa. *Illustrative Genera*:—Bixa, *Linn.*; Pangium, *Rumph.* There are over 100 species.

Properties and Uses.—Many plants of the order are feebly bitter and astringent, and have been used as stomachics; others are alterative, tonic, and emetic. The fruits of *Oncoba* and of some of the *Flacourtias* are edible and wholesome; but those of some other plants are poisonous. It is said, however, that by boiling, and maceration afterwards in cold water, the poisonous properties may, in some cases, be got rid of, as in the seeds of *Pangium edule*, the kernels of which are then used as a condiment, and for mixing in curries. But even these, according to Horsfield, act as a cathartic upon those unaccustomed to their use. The seeds of some species are employed as dyeing and colouring agents.

Cohort 3.—*Polygales.*

Order 65. Pittosporaceæ, the Pittosporum Order.—Character.—*Trees* or *shrubs*, with simple alternate exstipulate leaves. *Flowers* regular. *Sepals* and *petals* 4 or 5, hypogynous,

imbricate, deciduous. *Stamens* 5, hypogynous, alternate with the petals; *anthers* 2-celled. *Ovary* superior; *style* single; *stigmas* equal in number to the placentas, which are 2 or more, and either axile or parietal; *ovules* anatropous, horizontal or ascending. *Fruit* baccate, or a loculicidal capsule. *Seeds* numerous, with a minute embryo in copious fleshy albumen.

Distribution and Numbers.—They are chiefly Australian plants, but are occasionally found in Africa and some other parts of the globe. None, however, occur in Europe or America. *Illustrative Genera*:—Pittosporum, *Soland.*; Cheiranthera, *Cunningham.* The order includes about 80 species.

Properties and Uses.—These plants are chiefly remarkable for their resinous properties. Some have edible fruits, as certain species of *Billardiera.* A few are cultivated in this country on account of their flowers, as *Sollya*, *Billardiera*, &c.

Order 66. TREMANDRACEÆ, the Porewort Order.—Character.—Heath-like shrubs, with usually glandular hairs. *Leaves* exstipulate, alternate or whorled. *Flowers* axillary, solitary, pedicellate. *Sepals* 4 or 5, equal, slightly coherent, deciduous, and with a valvate æstivation. *Petals* corresponding in number to the sepals, deciduous, and with an involute æstivation. *Stamens* distinct, hypogynous, 8—10, 2 being placed before each petal; *anthers* 2- or 4-celled, with porous dehiscence. *Ovary* 2-celled; *ovules* 1—3 in each cell, pendulous; *style* 1 or 2; *stigmas* 1—2. *Fruit* 2-celled, a capsule with loculicidal dehiscence. *Seeds* pendulous, hooked at the chalazal end; *embryo* straight, in the axis of fleshy albumen; *radicle* next the hilum.

Distribution and Numbers.—All are natives of New Holland. *Illustrative Genera*:—Tetratheca, *Smith*; Tremandra, *R. Br.* The order includes about 16 species.

Properties and Uses.—Altogether unknown.

Order 67. POLYGALACEÆ, the Milkwort Order.—Character.—*Shrubs* or *herbs*. *Leaves* alternate or opposite, exstipulate, and usually simple. *Pedicels* bracteate. *Flowers* irregular, unsymmetrical, and arranged in a somewhat papilionaceous manner; but here the *wings* are derived from the calyx, whereas in the Leguminosæ they belong to the corolla. *Sepals* 5, very irregular, usually distinct; 3 are exterior, and of these 1 is posterior and 2 anterior; the other 2 are interior and lateral, usually petaloid, *and form the wings to the flower.* *Petals* hypogynous, usually 3, more or less united, of which 1, forming the keel, is larger than the rest, and placed at the anterior part of the flower; the keel is either naked, crested, or 3-lobed; the

other 2 petals are posterior, and alternate with the wings and posterior sepal of the calyx, and are often united to the keel; sometimes there are 5 petals, and then the 2 additional ones are of small size, and alternate with the wings and anterior sepals. *Stamens* hypogynous, 8; usually combined into a tube, unequal, the tube split on the side next to the posterior sepal; *anthers* clavate, innate, usually 1-celled, rarely 2-celled,

FIG. 1051.

FIG. 1052.

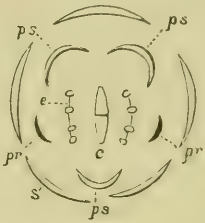


FIG. 1053.

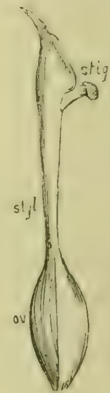


FIG. 1054.

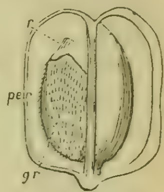


FIG. 1056.

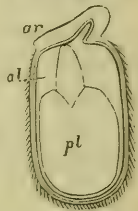


FIG. 1055.

Fig. 1051. A portion of the stem of the common Milkwort (*Polygala vulgaris*), with simple alternate exstipulate leaves, and irregular flowers. ——*Fig.* 1052. Diagram of the flower of the same. *s.* Sepals. *ps, ps, ps.* Posterior and anterior large petals. *pr, pr.* Lateral petals. *e.* Stamens. *c.* Carpels. ——*Fig.* 1053. Gynœcium of the same. *ov.* Ovary. *styl.* Style. *stig.* Stigma. ——*Fig.* 1054. Fruit with one cell opened. *per.* Pericarp. *gr.* Seed. *r.* Caruncula. ——*Fig.* 1055. Section of seed. *te.* Testa. *ar.* Caruncula. *al.* Albumen. *pl.* Embryo. ——*Fig.* 1056. Andrœcium of the same, with one-celled anthers dehiscing at their apex.

opening by a pore at their apex, or rarely by valves. *Ovary* 2—3-celled, one cell being frequently abortive; *ovules* solitary or twin, suspended; *style* simple, curved, sometimes hooded at the apex; *stigma* simple. *Fruit* varying in its nature and texture, indehiscent or opening in a loculicidal manner, occasionally winged. *Seeds* pendulous, smooth or hairy, with a caruncule next the hilum; *embryo* straight or nearly so, in copious fleshy albumen, and with the radicle towards the hilum.

Diagnosis (excluding *Krameria*).—Herbs or shrubs, with simple exstipulate leaves. Flowers irregular, unsymmetrical. Sepals and petals imbricate, not commonly corresponding in number, and usually arranged in a somewhat papilionaceous manner; odd petal anterior; odd sepal posterior. Stamens 8, hypogynous, usually combined; anthers generally 1-celled, with porous dehiscence. Fruit flattened, usually 2-celled and 2-seeded. Seeds with abundant fleshy albumen, and with a caruncule next the hilum.

Distribution and Numbers.—Some genera of the order are found in almost every part of the globe. The individual genera are, however, generally confined to particular regions, with the exception of the genus *Polygala*, which is very widely distributed, being found in almost every description of station, and in both warm and temperate regions. *Illustrative Genera*:—Polygala, *Linn.*; Monnina, *Ruiz et Pavon*; Soulamea, *Lam.* There are over 500 species.

Properties and Uses.—The greater part of the plants of this order are bitter and acrid, and their roots milky; hence they are frequently tonic, stimulant, and febrifugal. Some are emetic, purgative, diuretic, sudorific, or expectorant. The roots of the different species of *Krameria* are very astringent from the presence of tannic acid; they are commonly known under the name of *Rhatany roots*. A few species have edible fruits, and others abound in a saponaceous principle.

Order 68. VOCHYSIACEÆ, the Vochysia Order.—Character.—*Trees* or *shrubs*, with entire usually opposite leaves, which are furnished at the base with glands or stipules. *Flowers* very irregular and unsymmetrical. *Sepals* 4—5, united at the base, very unequal, the upper one spurred, *æstivation* imbricate. *Petals* 1, 2, 3, or 5, unequal, inserted upon the calyx; *æstivation* imbricate. *Stamens* 1 to 5, usually opposite the petals, or rarely alternate, arising from the bottom of the calyx, most of them sterile. *Ovary* superior or partially inferior, 3-celled, or rarely 1-celled; *placentas* axile; *style* and *stigma* 1. *Fruit* usually capsular, 3-cornered, 3-celled, with loculicidal dehiscence; or rarely indehiscent and 1-celled. *Seeds* usually winged, without albumen, erect.

This order is, on account of its Calycifloral character, frequently placed near *Combretaceæ*, but it is readily distinguished from it by its superior or nearly superior ovary. Lindley considered it most nearly allied to the *Violaceæ* and the *Polygalaceæ*—hence we place it here.

Distribution and Numbers.—Natives of equinoctial America. *Illustrative Genera* :—Vochysia, *Juss.*; Salvertia, *St. Hil.* There are about 50 species.

Properties and Uses.—Generally unimportant, although some are said to form useful timber.

Cohort 4.—*Caryophyllales.*

Order 3. FRANKENIACEÆ, the Frankenia Order.—Character. —*Herbs* or *undershrubs*, much branched, with small opposite exstipulate leaves, and sessile flowers. *Calyx* tubular, furrowed, persistent. *Petals* unguiculate, 4-6, hypogynous. *Stamens* 4 or more, hypogynous, distinct or connate at the base. *Ovary* superior, 1-celled, with parietal placentas. *Fruit* capsular, 1-celled, enclosed in the calyx, and dehiscing in a septicidal manner. *Seeds* numerous, minute; *embryo* straight, erect, in the middle of mealy albumen.

Distribution and Numbers.—The plants of this order are scattered over the globe, except in tropical India and North America, but they occur chiefly in the south of Europe and north of Africa. *Illustrative Genera* :—Frankenia, *Linn.*; Beatsonia, *Roxb.* There are about 24 species.

Properties and Uses.—Unimportant. They have been reputed mucilaginous and slightly aromatic. The leaves of a species of *Beatsonia* are used at St. Helena as a substitute for tea.

Order 69. CARYOPHYLLACEÆ, the Pink Order.—Character. —*Herbs.* *Stems* swollen at the nodes. *Leaves* opposite, entire, exstipulate, or with small membranous stipules, often connate at their base. *Inflorescence* cymose. *Flowers* generally hermaphrodite, or rarely unisexual. *Sepals* 4 or 5, distinct or united into a tube, persistent. *Petals* equal in number to the sepals, hypogynous, unguiculate, often deeply divided, sometimes absent, frequently raised above the calyx on a stalk. *Stamens* equal in number to the sepals, and then either alternate or opposite to them, or usually twice as numerous, or rarely fewer, frequently attached with the petals on a stalk above the calyx; *filaments* generally distinct, or sometimes united at the base, subulate; *anthers* innate. *Ovary* sessile, or supported with the petals and stamens on a short gynophore, generally 1-celled, and with a free central placenta, or rarely 2—5-celled; *styles* 2 to 5, papillose on their inner surface; *ovules* few or numerous, amphitropous. *Fruit* a 1-celled capsule, opening by 2—5 valves, or by 4—10 teeth at the apex, and having a free central placenta,

or rarely 2—5-celled with a loculicidal dehiscence, and with the placentas slightly attached to the dissepiments. *Seeds* usually numerous, rarely few; *embryo* curved round the albumen, which is of a mealy character, or rarely straight.

Diagnosis.—Herbaceous plants with the stems swollen at the nodes, and opposite entire exstipulate leaves; or rarely with small membranous stipules. Inflorescence cymose. Flowers usually hermaphrodite. Sepals, petals, and stamens with a quaternary or quinary arrangement, the petals sometimes absent. Calyx persistent. Stamens hypogynous; anthers innate. Ovary commonly 1-celled, styles 2—5. Capsule 1-celled, or rarely 2—5-celled; placenta usually free central, or in the 2—5-celled fruit slightly attached to the dissepiments. Seeds with the embryo curved round mealy albumen; or rarely straight.

Division of the Order and Illustrative Genera.—The order has been divided into four tribes or sub-orders as follows:—

Tribe 1. *Alsineæ.*—Sepals distinct, and opposite the stamens when the latter are equal to them in number. Styles free. Stipules none, or small and membranous. *Illustrative Genera*:—Alsine, *Wahlenb.*; Stellaria, *Linn.*; Spergula, *Linn.*

Tribe 2. *Sileneæ.*—Sepals cohering into a tube, and opposite the stamens when the latter are equal to them in number. No stipules. *Illustrative Genera*:—Dianthus, *Linn.*; Lychnis, *Linn.*

Tribe 3. *Mollugineæ.*—Sepals distinct or nearly so, and alternate with the stamens when the latter are equal to them in number. If the stamens are fewer than the sepals, they are then alternate with the carpels. No stipules. *Illustrative Genera*:—Mollugo, *Linn.*; Cœlanthum, *E. Mey.*

Tribe 4. *Polycarpeæ.*—Sepals distinct. Ovary sessile. Styles connate at the base. Stipules membranous. *Illustrative Genus*:—Polycarpon, *Linn.*

Distribution and Numbers.—They are natives chiefly of temperate and cold climates, When found in tropical regions they are generally on the sides and summits of mountains, commonly reaching the limits of eternal snow. The order contains nearly 1,100 species.

Properties and Uses.—The plants of this order possess no important properties. They are almost always insipid. Some of the wild species are eaten as food by small animals, and some have been said to increase the lacteal secretions of cows fed upon

them. This is supposed to be the case more particularly with *Vaccaria vulgaris*. *Saponaria officinalis* has been used in syphilis; it contains a peculiar principle called *saponin*. This principle has also been found in species of *Lychnis*, *Silene*, *Cucubalus*; and more especially in *Gypsophila Struthium*, to which latter plant it communicates well-marked saponaceous properties: hence it is commonly termed Egyptian Soap-root. The other species in which saponin is found also possess, to

Fig. 1057.

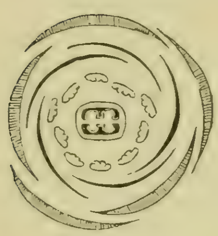


Fig. 1058.

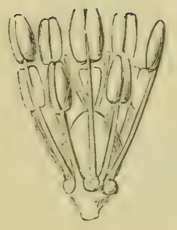


Fig. 1059.

Fig. 1060.

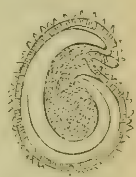


Fig. 1061.

Fig. 1057. Diagram of the flower of a species of *Dianthus*. — *Fig.* 1058. Vertical section of the flower of the same. — *Fig.* 1059. Sporophylls of a species of *Stellaria*.— *Fig.* 1060. Capsule of a species of *Dianthus*, dehiscing partially in a valvular manner so as to form four teeth at the apex.— *Fig.* 1061. Vertical section of the seed of Chickweed (*Stellaria media*).]

some extent, similar properties. Saponin is reputed to be poisonous in its nature.

Some of the plants have showy flowers, as the species of *Dianthus*, *Silene*, and *Lychnis*; but they are generally insignificant weeds. *Dianthus barbatus* is the Sweet-William of our gardens; *D. plumarius* is the parent of all the cultivated varieties of the common Pink; and *D. Caryophyllus*, the Clove Pink, is the origin of the Carnation and its cultivated varieties,

which are commonly known as Picotees, Bizarres, and Flakes.

Order 70. PARONYCHIACEÆ, the Knotwort Order.—Character.—*Herbs* or *shrubs*, with entire, simple, alternate or opposite leaves, and membranous stipules. *Flowers* minute. *Sepals* 5, or rarely 3 or 4, distinct or more or less united. *Petals* small or absent, perigynous. *Stamens* perigynous or somewhat hypogynous, either equal in number to the sepals and opposite to them, or more numerous, or rarely fewer. *Ovary* superior, 1- or 3-celled; *styles* 2—5. *Fruit* dry, 1- or 3-celled, dehiscent or indehiscent. *Seeds* either numerous upon a free central placenta, or solitary on a long funiculus arising from the base of the fruit; *albumen* farinaceous; *embryo* curved.

In the tribe Sclerantheæ there are no stipules.

Distribution and Numbers.—Natives chiefly of barren places in the south of Europe and the North of Africa. *Illustrative Genera*:—Illecebrum, *Linn.*; Corrigiola, *Linn.* There are about 100 species.

Properties and Uses.—Slightly astringent.

Order 71. PORTULACACEÆ the Purslane Order.—Character.—*Succulent herbs* or *shrubs*, with entire exstipulate leaves. *Flowers* unsymmetrical. *Sepals* 2, or rarely more, united at the base. *Petals* usually 5, distinct or united. *Stamens* perigynous or hypogynous, varying in number, sometimes opposite to the petals; *filaments* distinct; *anthers* 2-celled, versatile. *Ovary* superior, or rarely partially adherent. *Fruit* capsular, usually dehiscing transversely, or by valves; sometimes indehiscent; *placenta* free central. *Seeds* numerous or solitary; *embryo* curved round farinaceous albumen.

Distribution and Numbers.—Natives of waste dry places in various parts of the world, but chiefly at the Cape of Good Hope and in South America. *Illustrative Genera*:—Portulaca, *Tourn.*; Claytonia, *Linn.* There are about 190 species.

Properties and Uses.—The fleshy root of *Claytonia tuberosa* is edible. *Portulaca oleracea* has been used from the earliest times as a pot-herb, and in salads. It possesses cooling and antiscorbutic properties. Many of the plants have large showy flowers.

Order 72. TAMARICACEÆ, the Tamarisk Order.—Character.—*Shrubs* or *herbs*, with alternate entire scale-like leaves and spiked or racemose *inflorescence*. *Calyx* 4—5-partite, imbricate, persistent. *Petals* distinct, and attached to the calyx, withering, imbricate. *Stamens* hypogynous; *anthers* introrse.

Ovary superior, 1-celled, with 3 distinct styles. *Fruit* 1-celled, with 3 parietal or basal placentas, and dehiscing loculicidally by 3 valves. *Seeds* numerous, comose, without albumen, and having a straight embryo, with the radicle towards the hilum.

Distribution and Numbers.—The plants of this order usually grow by the seaside, or sometimes on the margins of rivers or lakes. They are most abundant in the basin of the Mediterranean, and are altogether confined to the northern hemisphere of the Old World. *Illustrative Genera* :—Tamarix, *Linn.*; Myricaria, *Desv.* There are about 40 species.

Properties and Uses.—The bark of these plants is astringent, slightly bitter and tonic. The ashes of some species of *Tamarix* contain much sulphate of soda.

Order 73. REAUMURIACEÆ, the Reaumuria Order.—This small order was first instituted by Ehrenberg. The plants belonging to it do not differ greatly from Hypericaceæ, except that they have a pair of appendages at the base of the petals, and shaggy seeds with a small quantity of mealy albumen. *Bentham and Hooker refer them to Tamaricaceæ.*

Distribution and Numbers.—Natives of the coast of the Mediterranean and the salt plains of Northern Asia. *Illustrative Genus* :—Reaumuria, *Hasselq.* There are 4 species.

Cohort 5.—*Guttiferales.*

Order 74. ELATINACEÆ, the Water-pepper Order.—Character.—Little annual marsh plants, with hollow creeping stems, and opposite leaves with interpetiolar membranous stipules. *Flowers* small and axillary. *Sepals* and *petals* 3—5, the latter, as well as the stamens, being distinct and hypogynous. *Ovary* superior; *styles* 3—5; *stigmas* capitate. *Fruit* capsular, 3—5-celled, placentation axile; dehiscence loculicidal. *Seeds* numerous, exalbuminous; *embryo* straight. This order has been variously placed, but it appears to be most nearly related to Hypericaceæ, although in some respects resembling the Alsineæ of the Caryophyllaceæ.

Distribution and Numbers.—The plants of this small order are scattered all over the world. *Illustrative Genera* :—Elatine, *Linn.*; Merimea, *Camb.* Lindley enumerates 22 species.

Properties and Uses.—They are generally considered acrid, hence the English name of the order.

Order 75. HYPERICACEÆ, the St. John's Wort Order.—Character.—*Herbs, shrubs*, or *trees*. *Leaves* opposite or very

rarely alternate, exstipulate, simple, entire, often dotted; sometimes bordered with black glands. *Flowers* regular. *Sepals* 4 or 5, persistent, unequal, distinct or united at the base, imbricate. *Petals* equal in number to the sepals, hypogynous, unequal-sided, frequently bordered with black glands; *æstivation* twisted. *Stamens* usually numerous, rarely few, hypogynous, polyadelphous, or rarely distinct, or monadelphous, sometimes having glands alternating with the bundles of stamens; *filaments* filiform; *anthers* 2-celled, with longitudinal dehiscence. *Ovary* 1-celled, formed of from 3 to 5 carpels, which are partially inflected so as to project into the cavity; or 3—5-celled by the union of the dissepiments in the centre; *styles* equal in number to the carpels; *stigmas* usually capitate or truncate, rarely 2-lobed. *Fruit* capsular, usually 3—5-celled, sometimes

Fig. 1062.

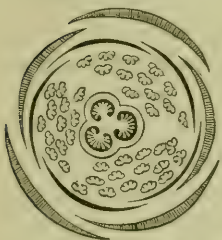


Fig. 1063.

Fig. 1064.

Fig. 1062. Diagram of the flower of a species of St. John's Wort (*Hypericum*).——*Fig.* 1063. Vertical section of the flower of the same.——*Fig.* 1064. Vertical section of the seed.

1-celled; *placentas* axile or parietal, dehiscence septicidal. *Seeds* minute, numerous, exalbuminous; *embryo* straight or curved.

Diagnosis.—Leaves entire, often dotted, exstipulate. Flowers regular. Sepals and petals hypogynous, with a quaternary or quinary distribution; the former with an imbricate æstivation; the latter unequal-sided, commonly marked with black glands, and having a twisted æstivation. Stamens hypogynous, usually numerous and polyadelphous, rarely few, and then distinct or monadelphous; anthers 2-celled, opening longitudinally. Styles several. Fruit 1-celled, or 3—5-celled. Seeds numerous, exalbuminous.

Distribution and Numbers.—The plants are generally distributed over the globe, inhabiting both temperate and hot regions, and almost all varieties of soil. *Illustrative Genera :*—Hypericum, *Linn.*: Vismia, *Vell.* There are about 280 species.

Properties and Uses.—They abound usually in a resinous yellow juice, which is frequently purgative, as in *Vismia guianensis* and *V. micrantha*. Other plants of the order, as *Hypericum perforatum* and *H. Androsæmum*, have tonic and astringent properties, and *Cratoxylon Hornschuchii* is slightly astringent and diuretic.

Order 76. GUTTIFERÆ or CLUSIACEÆ, the Gamboge or Mangosteen Order.—Character.—*Trees* or *shrubs*, sometimes parasitical, with a resinous juice. *Leaves* coriaceous, entire, simple, opposite, exstipulate. *Flowers* usually perfect, sometimes unisexual by abortion. *Sepals* 2, 4, 5, 6, or 8, imbricate, usually persistent, frequently unequal and petaloid. *Petals* hypogynous, equal in number to, or a multiple of, the sepals, sometimes passing by imperceptible gradations into them. *Stamens* usually numerous, rarely few, hypogynous, distinct, monadelphous, or polyadelphous; *anthers* adnate, not beaked, introrse or extrorse, opening by a pore or transverse slit, 2-celled or sometimes 1-celled. *Disc* fleshy, or rarely with five lobes. *Ovary* superior, 1- or many-celled; *style* absent; *stigmas* peltate or radiate; *placentas* axile. *Fruit* dehiscent or indehiscent, 1- or many-celled. *Seeds* solitary or numerous, frequently arillate, without albumen; *embryo* large, straight, with minute cotyledons.

FIG. 1065.

Fig. 1065. Flowering stem and fruit of the Mangosteen plant (*Garcinia Mangostana*).

Diagnosis.—Trees or shrubs with a resinous juice, and with opposite, simple, coriaceous, exstipulate leaves. Sepals and petals usually having a binary arrangement of their parts; the former imbricate and frequently unequal; the latter equal and hypogynous. Stamens almost always numerous; anthers adnate, without a beak, opening by a pore or transversely. Disc fleshy or lobed. Ovary superior, with sessile radiate stigmas, and axile placentas. Seeds exalbuminous; cotyledons minute.

Distribution and Numbers.—Exclusively tropical, and especially occurring in moist situations. The larger proportion are natives of South America, but a few occur in Madagascar

and the African continent. *Illustrative Genera* :—Clusia, *Linn.*; Garcinia, *Linn.* There are about 250 species.

Properties and Uses.—The plants of this order are chiefly remarkable for yielding a yellow gum-resin of an acrid and purgative nature. In many cases, however, the fruits are edible, and are held in high estimation for their delicious flavour. The seeds of some are oily, and other plants of the order are good timber-trees.

Order 77. TERNSTRŒMIACEÆ or CAMELLIACEÆ, the Tea Order. —Character.—*Trees* or *shrubs*. *Leaves* leathery, alternate, usually exstipulate, and sometimes dotted. *Flowers* regular, and generally very showy, rarely polygamous. *Sepals* 5 or 7, coriaceous, imbricate; often deciduous. *Petals* 5, 6, or 9, often united at the base, imbricate. *Stamens* hypogynous, numerous, distinct or united by their filaments into one or several bundles; *anthers* 2-celled, versatile or adnate. *Ovary* superior, many-celled; *styles* filiform, 3—7. *Fruit* capsular, 2—7-celled; *placentas* axile; dehiscence various. *Seeds* few, sometimes arillate; *albumen* wanting or in very small quantity; *embryo* straight or folded; *cotyledons* large and oily; *radicle* towards the hilum.

Diagnosis.—Trees or shrubs, with alternate usually exstipulate leathery leaves. Sepals and petals imbricate in æstivation, and having no tendency to a quaternary arrangement. Stamens numerous, hypogynous; anthers versatile or adnate. Ovary superior, styles filiform. Seeds solitary or very few, attached to axile placentas; albumen wanting or in very small quantity.

Distribution and Numbers.—These plants, which are mostly ornamental trees or shrubs, are chiefly natives of South America, but a few are found in the East Indies, China, and North America. One species only occurs in Africa. There are no European species, although a few are cultivated in Europe. *Illustrative Genera* :—Ternstrœmia, *Mut.*; Camellia, *Linn.* The order, as defined above, following Lindley, contains about 130 species.

Properties and Uses.—Generally speaking, we know but little of the properties of the plants of this order; but some, as those from which China tea is prepared, are moderately stimulant, astringent, and slightly soothing and sedative.

Order 78. MARCGRAAVIACEÆ, the Marcgraavia Order.—*Diagnosis.*—This is a small order which is generally regarded as allied to Clusiaceæ and Hypericaceæ. The species belonging to it are chiefly distinguished from Clusiaceæ by their unsymmetri-

cal flowers, versatile anthers, and very numerous minute seeds. Some genera of the order are remarkable for their peculiar bracts, which become hooded, pouched, or spurred. They are distinguished from Hypericaceæ chiefly by their unsymmetrical flowers, equal-sided petals, distinct stamens, and sessile stigmas. They are sometimes placed as a tribe of Ternstrœmiaceæ.

Distribution and Numbers.—Generally natives of equinoctial America. *Illustrative Genera* :—Ruyschia, *Jacq.*; Marcgraavia, *Plum.* There are 26 species.

Properties and Uses.—Scarcely anything is known of their properties. *Marcgraavia umbellata* is reputed to be diuretic and antisyphilitic.

Order 79. RHIZOBOLACEÆ, the Souari-nut Order.—Character.—Large *trees*. *Leaves* opposite, coriaceous, digitate, exstipulate, with an articulated stalk. *Sepals* 5 or 6, more or less united, imbricate. *Petals* 5 to 8, unequal. *Stamens* very numerous, slightly monadelphous, in two whorls, the inner shorter and often abortive, inserted with the petals on an hypogynous disc; *anthers* 2-celled, with longitudinal dehiscence. *Ovary* 4-, 5-, or many-celled; *styles* short, as many as the cells of the ovary; *stigmas* small; *ovules* solitary, attached to the axis. *Fruit* consisting of several combined indehiscent 1-seeded nuts. *Seeds* reniform, exalbuminous, with the funiculus expanded so as to form a spongy excrescence; *radicle* very large, forming the great bulk of the embryo; *cotyledons* very small. This order is frequently incorporated with the Ternstrœmiaceæ.

Diagnosis.—Large trees, with opposite digitate exstipulate leaves, with an articulated stalk. Flowers regular, hypogynous. Petals equal-sided, and inserted with the numerous stamens on an hypogynous disk. Styles very short. Seed solitary, exalbuminous, with a very large radicle, and two very small cotyledons.

Distribution and Numbers.—The order contains but 2 genera, including 8 species, all of which are large trees, natives of the forests in the hottest parts of South America. *Illustrative Genus* :—Caryocar, *Linn.*

Properties and Uses.—Some of the trees are valuable for their timber, others yield edible nuts, and some an excellent oil.

Order 80. DIPTERACEÆ, the Sumatra Camphor Order.—Character.—Large *trees* with a resinous juice. *Leaves* alternate, involute, feather-veined, with large convolute deciduous stipules. *Calyx* 5-lobed, tubular, unequal, persistent,

imbricate, ultimately enlarged into winglike expansions. *Petals* 5, hypogynous, often coherent at the base; *æstivation* twisted. *Stamens* numerous, hypogynous, distinct or united in an irregular manner by their filaments so as to become somewhat polyadelphous; *anthers* innate, 2-celled, subulate, prolonged above or beaked. *Ovary* superior, 3-celled; *ovules* pendulous; *style* and *stigma* simple. *Fruit* 1-celled, dehiscent or indehiscent, surrounded by the enlarged permanent calyx. *Seed* solitary, exalbuminous; *radicle* superior.

Distribution and Numbers.—Natives exclusively of the forests of the tropical East Indies, with the exception of the genus *Lophira*, which belongs to tropical Africa. (The latter genus, by Endlicher and others, has been separated from the Dipteraceæ, and placed in an order by itself under the name of Lophiraceæ. The chief characters of distinction are its 1-celled ovary with numerous ovules on a free central placenta, and its inferior radicle.) *Illustrative Genera:*—Dipterocarpus, *Gärtn.*; Dryobalanops, *Gärtn.* There are about 50 species belonging to this order.

Properties and Uses.—These plants form very large and handsome trees, which abound in an oleo-resinous juice. To the presence of this they owe their peculiar properties.

Order 81. CHLÆNACEÆ, the Sarcolæna Order.—Character.—*Trees* or *shrubs*. *Leaves* entire, alternate, with large deciduous convolute stipules. *Flowers* regular, unsymmetrical, furnished with an involucre: the *involucre* surrounding 1—2 flowers, and persistent. *Sepals* 3, imbricate. *Petals* 5, convolute, sometimes united at the base. *Stamens* generally very numerous, rarely but 10, monadelphous; *anthers* roundish, 2-celled. *Ovary* 3-celled; *style* 1; *stigma* trifid. *Fruit* capsular, 3-celled or rarely 1-celled; *placentas* axile. *Seeds* solitary or numerous, suspended; *embryo* in the axis of fleshy albumen; *cotyledons* leafy; *radicle* superior.

Diagnosis.—Readily distinguished among the Thalamifloræ by their alternate simple stipulate leaves and involucrate flowers, which are regular and unsymmetrical. The calyx is also imbricate, the stamens monadelphous, and the seed has abundant albumen.

Distribution and Numbers.—There are but 8 species included in this order, all of which are natives of Madagascar. *Illustrative Genus:*—Sarcolæna, *Thouars*.

Properties and Uses.—Altogether unknown.

Cohort 6.—*Malvales.*

Order 82. MALVACEÆ, the Mallow Order.—Character.—*Herbs, shrubs*, or *trees*. *Leaves* alternate, often downy, more or less divided in a palmate manner, stipulate. *Flowers* regular, usually axillary, and often surrounded by an involucre or epicalyx. *Sepals* usually 5, rarely 3 or 4, more or less united; with valvate or some form of circular æstivation. *Petals*

FIG. 1066.

FIG. 1067.

FIG. 1068.

FIG. 1069.

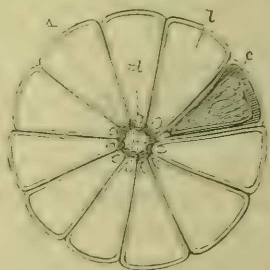


Fig. 1066. Diagram of the flower of a species of *Malva*. The three external lines represent bracts, which together form an epicalyx or involucre.——*Fig.* 1067. Vertical section of the flower of a Mallow.——*Fig.* 1068. Pistil of the same surrounded by the inferior calyx and involucre.——*Fig.* 1069. Horizontal section of the fruit of *Malva sylvestris*. *a.* Axis. *pl.* Placenta. *l.* An empty cell. *c.* Embryo with twisted cotyledons.

hypogynous, equal in number to the divisions of the calyx, with a twisted æstivation, either attached to the column formed by the united stamens or free. *Stamens* hypogynous, numerous, monadelphous; *anthers* 1-celled, reniform, with transverse dehiscence. *Ovary* superior, consisting of several carpels, which are either apocarpous, or united so as to form a compound ovary with as many cells as there are carpels; *placentas*

attached to the ventral sutures when the carpels are apocarpous, or axile when the ovary is compound; *styles* equalling the carpels in number, united or distinct. *Fruit* either a carcerule, that is, consisting of a number of 1-celled, indehiscent, 1- or many-seeded carpels; or a capsule with loculicidal or septicidal dehiscence, and numerous seeds. *Seeds* sometimes hairy; *albumen* none or in small quantity; *embryo* curved; *cotyledons* much twisted.

Diagnosis.—Leaves alternate, palmately veined, simple, stipulate. Flowers regular. Calyx with valvate or some form of circular æstivation. Petals twisted in æstivation. Stamens hypogynous, numerous; anthers 1-celled, reniform, dehiscing transversely; filaments united so as to form a column. Carpels distinct or united. Seeds with very little or no albumen; embryo curved; cotyledons twisted.

Division of the Order and Illustrative Genera.—This order may be divided into three tribes as follows:—

Tribe 1. *Malveæ.*—Flowers furnished with an involucre or epicalyx (*fig.* 1066). Fruit consisting of separate carpels (apocarpous) (*fig.* 1069). *Illustrative Genera:*—Malva, *Linn.*; Althæa, *Linn.*

Tribe 2. *Hibisceæ.*—Flowers furnished with an involucre. Fruit formed of united carpels (syncarpous). *Illustrative Genera:*—Hibiscus, *Linn.*; Gossypium, *Linn.*

Tribe 3. *Sideæ.*—Flowers without an involucre. Fruit apocarpous or syncarpous. *Illustrative Genus:*—Sida, *Linn.*

Distribution and Numbers.—These plants are chiefly natives of the tropics and the warmer parts of temperate regions. They diminish gradually as we approach the north, and are altogether absent from the frigid zone. There are more than 1,000 species.

Properties and Uses.—No plant of this order possesses any deleterious properties. The order is generally characterised by mucilaginous and demulcent qualities. From the bast of many species strong and tough fibres are obtained, and the hairs covering the seeds of certain species constitute cotton.

Order 83. STERCULIACEÆ, the Silk-cotton Order.—Character.—*Trees* or *shrubs*, sometimes climbing. *Leaves* alternate, simple or compound, with deciduous stipules. *Flowers* usually perfect, sometimes by abortion unisexual, regular or irregular, often surrounded by an involucre. *Calyx* and *corolla* resem-

bling the Malvaceæ, always, however, having five parts; but the petals are sometimes absent. *Stamens* usually united by their filaments into a column, and indefinite, or rarely few and distinct; *anthers* usually 2-celled, or rarely 1-celled. *Carpels* 3 or 5, either distinct or united so as to form a compound ovary, sessile or stalked, or rarely more numerous or solitary; *styles* equal in number to the carpels, distinct or united; *ovules* usually definite, sometimes indefinite. *Fruit* either composed of a number of follicles, or capsular, or rarely baccate. *Seeds* with fleshy-oily albumen or none; *embryo* straight or curved; *cotyledons* either plicate or rolled round the plumule.

The order Byttneriaceæ of some botanists is here included in Sterculiaceæ.

Diagnosis.—The plants of this order are at once known among the Thalamifloræ by their valvate 5-partite calyx; twisted corolla consisting of 5 distinct petals; numerous perfect stamens united by their filaments into a column; and usually by their 2-celled anthers. The character presented by the anthers should be particularly noticed, as that alone, in most cases, at once distinguishes them from the Malvaceæ, which in many other respects they closely resemble; indeed the Sterculiaceæ have been combined with the Malvaceæ. It should, however, also be observed, that the flowers of some of the Sterculiaceæ are unisexual by abortion.

Distribution and Numbers.—Natives chiefly of the tropics or of very warm regions; but some of the species are found scattered in almost every quarter of the globe, except Europe. *Illustrative Genera*:—Sterculia, *Linn.*; Helicteres, *Linn.*; Theobroma, *Linn.* There are more than 500 species belonging to this order.

Properties and Uses.—In their properties the plants of this order resemble the Malvaceæ: thus, they are generally mucilaginous, demulcent, and emollient; some have a hairy covering to their seeds; and others yield useful bast-fibres. The cottony covering of their seeds, and the fibres yielded by certain plants of this order, are not, however, to be compared in importance with the similar products of the Malvaceæ. Some plants are reputed to be diuretic, emetic, or purgative.

Order 84. TILIACEÆ, the Lime-tree or Linden Order.—Character.—*Trees*, *shrubs*, or rarely *herbs*. *Leaves* simple, alternate, with deciduous stipules. *Sepals* 4 or 5, distinct or united, valvate in æstivation, deciduous. *Petals* equal in number

to the sepals, entire or divided, or rarely wanting, imbricate. *Stamens* hypogynous, usually numerous, distinct, or polyadelphous; *anthers* 2-celled, opening longitudinally, or by pores at the apex. *Disc* glandular, hypogynous. *Carpels* 2—10, which are generally united so as to form a compound, many-celled ovary, sometimes distinct; *placentas* axile; *style* 1; *stigmas* equal in number to the carpels. *Fruit* dry or pulpy, sometimes samaroid, usually many-celled, or rarely 1-celled by abortion. *Seeds* solitary or numerous; *embryo* erect, straight, in the axis of fleshy albumen; *cotyledons* flat and leafy; *radicle* next the hilum.

FIG. 1070.

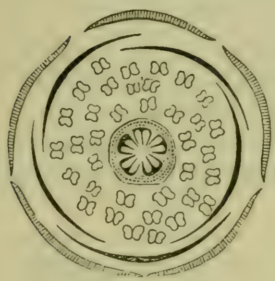


FIG. 1071.

FIG. 1072.

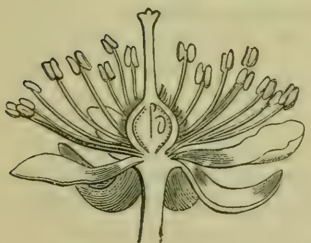


Fig. 1070. Diagram of the flower of the Lime.——*Fig.* 1071. Vertical section of the flower of the same (*Tilia europæa*).——*Fig.* 1072. Peduncle of the Lime, bearing two flower-buds and a fully expanded flower.

Diagnosis.—This order resembles, in many respects, the Malvaceæ and Sterculiaceæ. It may be at once distinguished from them by having a glandular disc, and by the stamens not being monadelphous; and from the Malvaceæ also by the anthers being 2-celled. From all other Thalamifloræ the plants of this order may be known by their alternate simple stipulate leaves; valvate æstivation of calyx, which is also deciduous; floral envelopes in 4 or 5 divisions; stamens either distinct or polyadelphous; anthers 2-celled; hypogynous glandular disc; many-celled fruit with axile placentas; and embryo erect, straight in the axis of fleshy albumen.

Division of the Order and Illustrative Genera.—The order has been divided into two tribes, as follows:—

Tribe 1. *Tilieæ.*—Corolla with entire petals, or wanting; anthers dehiscing longitudinally. *Illustrative Genera*:—Corchorus, *Linn.*; Tilia, *Linn.*

Tribe 2. *Elæocarpeæ.*—Petals divided, anthers opening by pores at the apex. *Illustrative Genera*:—Elæocarpus, *Linn.*; Vallea, *Mut.*

Distribution and Numbers.—A few are found in the northern parts of the world, where they form large trees; but the plants of this order are chiefly tropical, and are there found as herbs, shrubs, or trees. There are about 350 species.

Properties and Uses.—In their properties the Tiliaceæ resemble the Malvaceæ. They are altogether innocuous, and are generally mucilaginous, emollient, and demulcent. Many of them also yield fibres, which are much used for manufacturing purposes. Some are valuable timber-trees, and some have edible fruits.

Artificial Analysis of the Orders in the Sub-class Polypetalæ.

Series 1. THALAMIFLORÆ.

1. FLOWERS with more than 20 stamens.

A. *Leaves without stipules.*

a. *Carpels more or less distinct (at least as to the styles), or solitary.*

1. Stamens distinct.
   - Carpels immersed in a fleshy tabular thalamus . . . . *Nymphæaceæ (Nelumboneæ).*
   - Carpels not immersed in a thalamus.
     - Embryo with endosperm and perisperm *Nymphæaceæ (Cabombeæ).*
     - Embryo naked, very minute.
       - Seeds arillate . . . . *Dilleniaceæ.*
       - Seeds exarillate. Albumen fleshy and homogeneous.
         - Flowers hermaphrodite . . . *Ranunculaceæ.*
         - Flowers unisexual . . . . *Schizandraceæ.*
       - Seeds usually exarillate. Albumen ruminated . . . . *Anonaceæ.*
2. Stamens united in one or more parcels.
   - Calyx imbricate.
     - Seeds smooth . . . . . . *Hypericaceæ.*
     - Seeds shaggy . . . . . . *Reaumuriaceæ.*

b. *Carpels wholly combined (at least as to the ovaries), with more than one placenta; or with a free central placenta.*

Placentas parietal, in distinct lines.
Anthers versatile. Juice watery . . . *Capparidaceæ.*
Anthers innate. Juice milky . . . *Papaveraceæ.*
Placentas parietal, spread over the lining of the fruit . . . . *Bixaceæ.*
Placentas covering the dissepiments . *Nymphæaceæ (Nymphææ).*
Placentas in the axis.
Stigma large, broad, and petaloid . . . *Sarraceniaceæ.*
Stigma simple. Calyx imbricate.
Leaves compound . . . . . . *Rhizobolaceæ.*
Leaves simple.
Petals equal in number to the sepals.
Seeds few . . . . . . *Guttiferæ.*
Seeds numerous. Petals flat . . *Marcgraaviaceæ.*
Seeds numerous. Petals crumpled . *Cistaceæ.*
Petals not equal in number to the sepals.
Styles not perfectly combined . *Ternstrœmiaceæ.*
Placentas free central . . . . . *Portulacaceæ.*

B. *Leaves with stipules.*

a. *Carpels more or less distinct (at least as to the styles).*

Carpels numerous . . . . . . *Magnoliaceæ.*

b. *Carpels wholly combined (at least as to the ovaries), with more than one placenta.*

Placentas parietal . . . . . . *Bixaceæ.*
Placentas in the axis.
Calyx with an imbricate æstivation.
Flowers involucrate . . . . . *Chlænaceæ.*
Flowers not involucrate . . . . *Cistaceæ.*
Calyx with a valvate æstivation.
Stamens monadelphous. Anthers 2-celled *Sterculiaceæ.*
Stamens monadelphous. Anthers 1-celled *Malvaceæ.*
Stamens monadelphous. Calyx irregular, and enlarged in the fruit . . . *Dipteraceæ.*
Stamens quite distinct . . . . *Tiliaceæ.*

2. Flowers with less than 20 stamens.

A. *Leaves without stipules.*

a. *Carpels more or less distinct, or solitary.*

Anthers with recurved valves . . . . *Berberidaceæ.*
Anthers with longitudinal dehiscence.
Albumen abundant, embryo minute.
Flowers unisexual. Seeds usually numerous . . . . . . *Lardizabalaceæ.*

Flowers perfect.
Embryo with endosperm and perisperm . . . . *Nymphæaceæ* (*Cabombeæ*).
Embryo without perisperm.
Albumen homogeneous.
Sepals 2 . . . . . . *Fumariaceæ*.
Sepals more than 2 . . . . *Ranunculaceæ*.
Albumen ruminated. Shrubs .. . *Anonaceæ*.
Albumen in small quantity, or altogether wanting.
Flowers unisexual . . . . *Menispermaceæ*.
Flowers perfect . . . . *Calycanthaceæ*.

b. *Carpels wholly combined* (*at least as to the ovaries*).

Placenta parietal.
Stamens tetradynamous . . . . *Cruciferæ*.
Stamens not tetradynamous.
Large hypogynous disc.
Flowers tetramerous. Fruit closed at the apex . . . . . . *Capparidaceæ*.
Flowers not tetramerous. Unripe fruit usually open at the apex . . . *Resedaceæ*.
Small hypogynous disc, or none.
Albumen abundant.
Flowers irregular . . . . *Fumariaceæ*.
Flowers regular. Sap milky. Fruit without central pulp . . . *Papaveraceæ*.
Fruit with central pulp, or fleshy.
Sap watery . . . . *Bixaceæ*.
Albumen in small quantity, or wanting.
Calyx tubular, furrowed . . . *Frankeniaceæ*.
Placentas covering the dissepiments . *Nymphæaceæ* (*Nymphææ*).
Placentas axile or free central.
Styles distinct to the base.
Calyx imbricate.
Seeds smooth. Petals unequal-sided, without appendages . . . . *Hypericaceæ*.
Seeds shaggy. Petals unequal-sided, usually with appendages at the base *Reaumuriaceæ*.
Calyx slightly imbricate.
Petals not twisted in æstivation.
Ovary with a free central placenta . *Caryophyllaceæ*.
Styles more or less combined.
Calyx imbricate, in an irregular broken whorl.
Flowers symmetrical . . . . *Guttiferæ*.
Flowers unsymmetrical, papilionaceous *Polygalaceæ*.

Calyx slightly imbricate, in a complete whorl.
Carpels 4 or more.
Ovary 1-celled, with a free central placenta . . . . . . *Portulacaceæ.*
Carpels less than 4.
Seeds comose . . . . . . *Tamaricaceæ.*
Seeds not comose.
Ovules pendulous. Petals twisted in æstivation . . . . *Canellaceæ.*
Ovules ascending or horizontal.
Petals imbricate in æstivation . *Pittosporaceæ.*
Calyx valvate, or but very slightly imbricate.
Anthers opening by pores . . . *Tremandraceæ.*

B. *Leaves with stipules.*

a. *Carpels distinct, or solitary.*

Anthers with recurved valves. Carpel solitary *Berberidaceæ.*

b. *Carpels wholly combined (at least as to the ovaries), with more placentas than one.*

Placentas parietal.
Leaves with involute vernation. Anthers crested, and turned inwards . . . *Violaceæ.*
Stamens opposite to the petals. Anthers naked, and turned outwards . . . *Sauvagesiaceæ.*
Placentas in the axis.
Styles distinct to the base.
Calyx imbricate, in an irregular broken whorl.
Petals small, sessile . . . . . *Elatinaceæ.*
Calyx slightly imbricate, in a complete whorl.
Petals minute . . . . . . *Paronychiaceæ.*
Calyx valvate . . . . . . *Tiliaceæ.*
Styles more or less combined.
Calyx imbricate, in an irregular broken whorl.
Flowers surrounded by an involucre . *Chlænaceæ.*
Calyx slightly imbricate, in a complete whorl.
Sepal spurred . . . . . . *Vochysiaceæ.*
Calyx valvate.
Stamens united by their filaments into a column . . . . . . *Sterculiaceæ.*
Stamens not united into a column . . *Tiliaceæ.*

In order to prevent the student being misled, and thus referring plants to their wrong positions in the Vegetable Kingdom, it should be particularly noticed, that although the general character of the Thalamifloræ is to have dichlamydeous flowers and polypetalous corollas, yet exceptions do occur

occasionally to both these characters. Thus, we find apetalous genera and species in *Ranunculaceæ*, *Magnoliaceæ*, *Berberidaceæ*, *Sarraceniaceæ*, *Menispermaceæ*, *Papaveraceæ*, *Cruciferæ*, *Canellaceæ*, *Bixaceæ*, *Violaceæ*, *Caryophyllaceæ*, *Paronychiaceæ*, *Scleranthaceæ*, *Malvaceæ*, *Sterculiaceæ*, and *Tiliaceæ*.

Again, in the orders *Anonaceæ*, *Pittosporaceæ*, *Polygalaceæ*. *Portulacaceæ*, *Tamaricaceæ*, *Ternstrœmiaceæ*, *Rutaceæ*, and *Dipteraceæ*, we find some monopetalous species and genera.

In *Dilleniaceæ*, *Papaveraceæ*, *Capparidaceæ*, *Resedaceæ*, *Violaceæ*, *Caryophyllaceæ*, *Portulacaceæ*, *Malvaceæ*, and *Sterculiaceæ*, some of the species have stamens more or less perigynous instead of hypogynous. Again, in some orders, as in certain *Ranunculaceæ*, *Calycanthaceæ*, *Anonaceæ*, *Nymphæaceæ*, *Portulacaceæ*, *Capparidaceæ*, *Polygalaceæ*, *Bixaceæ*, *Ternstrœmiaceæ*, *Vochysiaceæ*, *Tiliaceæ*, and *Dipteraceæ*, the calyx is more or less superior.

Synopsis of the British Natural Orders of the Series Thalamifloræ.

A. Corolla polypetalous, hypogynous.

1. Ovaries many, distinct or united, each with a style, or solitary with one lateral placenta.
  - Corolla regular.
    - Sepals free. Stamens hypogynous.
      - Stamens ∞, usually many. Anthers dehiscing by slits . . . . . *Ranunculaceæ.*
      - Stamens equal and opposite to petals. Anthers dehiscing by valves . . *Berberidaceæ.*
  - Corolla irregular.
    - Leaves exstipulate. Stamens diadelphous . *Fumariaceæ.*
2. Ovary solitary, with parietal placentation.
  - Corolla regular.
    - Petals 4.
      - Stamens ∞. Sepals 2, fugacious . . . *Papaveraceæ.*
      - Stamens tetradynamous . . . . . *Cruciferæ.*
    - Petals 5.
      - Sepals distinct, 3 inner twisted in the bud, 2 outer smaller or wanting. Stamens ∞ *Cistaceæ.*
      - Sepals united below. Stamens iso- or diplostemonous inserted on a disc . *Tamaricaceæ.*
    - Petals 4–5, clawed. Placentas 3 . . . *Frankeniaceæ.*
    - Petals and sepals acyclic . . . . . *Nymphæaceæ.*
  - Corolla irregular.
    - Leaves stipulate. Sepals 5. Stamens 5 free *Violaceæ.*
    - Leaves exstipulate. Fruit open at the end. Stamens ∞ . . . . *Resedaceæ.*
3. Ovary solitary, with axile or free central placentation.
  - Calyx imbricate in bud.
    - Corolla regular.
      - Placentation free central.
        - Calyx tubular . . . . . . { *Caryophyllaceæ* (*Sileneæ*).

Sepals distinct.
Stamens opposite to the petals.
Sepals 2 . . . . . . *Portulacaceæ.*
Sepals 3–5.
Stamens 10 or fewer. Stipules 0 . . . *Caryophyllaceæ (Alsineæ).*
Stamens 5. Leaves stipulate. Petals distinct . . *Caryophyllaceæ (Polycarpeæ).*
Petals minute or 0 . . *Paronychiaceæ.*
Placentation axile.
Stamens free. Styles 3–5 . . . *Elatinaceæ.*
Stamens polyadelphous . . . . *Hypericaceæ.*
Calyx valvate in the bud.
Stamens columnar . . . . *Malvaceæ.*
Stamens free . . . . . *Tiliaceæ.*

B. Corolla partly gamopetalous, or with petals slightly united at their base . . . . *Polygalaceæ.*

Series II.—*Discifloræ.*

Cohort 1.—*Geraniales.*

Order 85. LINACEÆ, the Flax Order.—Character.—*Herbs* or rarely *shrubs*. *Leaves* alternate, opposite, or rarely verticillate, simple, entire, exstipulate, or rarely stipulate. *Inflorescence* cymose. *Flowers* regular, symmetrical, generally very showy. *Calyx* imbricate, with 3, 4, or 5 sepals, persistent. *Petals* 4—5, unguiculate, very deciduous, twisted in æstivation. *Stamens* 4—5, united at the base so as to form an hypogynous

FIG. 1073.

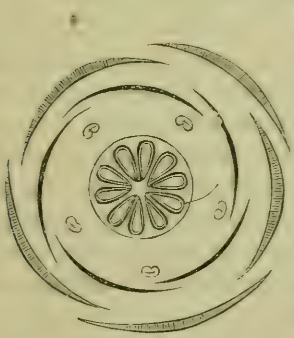


FIG. 1074.

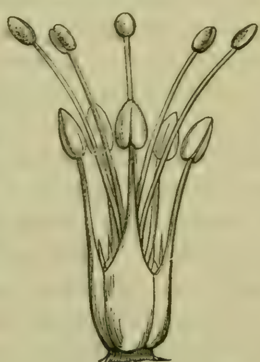


FIG. 1075.

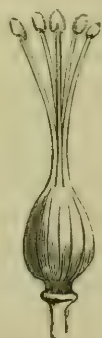


Fig. 1073. Diagram of the flower of the Flax Plant (*Linum usitatissimum*).——*Fig.* 1074. Sporophylls of the same, showing the monadelphous stamens surrounding the pistil.——*Fig.* 1075. Pistil of the same, with distinct styles and capitate stigmas.

ring, from which proceed 5 tooth-like processes (*staminodes*) which alternate with the fertile stamens, and are opposite to the petals. *Disc* none or glandular. *Ovary* compound, its cells usually corresponding in number to the sepals; *styles* 3—5; *stigmas* capitate. *Fruit* a septicidal capsule, each cell more or less perfectly divided into two by a spurious dissepiment proceeding from the dorsal suture, and having a single seed in each division. *Seed* compressed, with or without albumen; *embryo* straight, with the radicle towards the hilum.

Diagnosis.—Herbs or very rarely shrubs, with simple entire leaves, which are usually exstipulate. Flowers regular, symmetrical. Sepals, petals, and stamens 3—5 each; the sepals persistent and imbricate; the petals fugacious and twisted in æstivation; the fertile stamens united at their bases, and having little tooth-like staminodes alternating with them. Ovary 3—5-celled, styles distinct, stigmas capitate. Fruit a septicidal capsule, each cell more or less divided by a spurious dissepiment, and each division containing one seed. Seeds compressed, with or without albumen, and a straight embryo.

The plants of the order *Erythroxylaceæ* of some botanists, which, following Bentham and Hooker, we include in this order, are exceptional in each petal having at its base two scales, in their drupaceous fruit, and woody stem.

Distribution and Numbers.—Chiefly natives of the south of Europe, Brazil, and some other parts of South America, West Indies, and the north of Africa, but more or less distributed over most regions of the globe. *Illustrative Genera*:—Linum, *Linn.*; Radiola, *Gmelin.* There are about 160 species.

Properties and Uses.—The plants of this order are generally remarkable for the tenacity of their bast fibres, and also for the mucilage and oil contained in their seeds; hence the latter are emollient and demulcent. A few of the plants are bitter and purgative, and some are stimulant and sedative. Others are tonic, and some are used for dyeing red.

Order 86. HUMIRIACEÆ, the Humirium Order.—Character.—*Trees* or *shrubs* with a balsamic juice. *Leaves* alternate, simple, coriaceous, exstipulate. *Calyx* 5-partite, imbricate. *Petals* 5, imbricate. *Stamens* hypogynous, 20 or more, monadelphous; *anthers* 2-celled; *connective* elongated beyond the anther lobes. *Ovary* superior, usually surrounded by a *disc*, 5-celled; *ovules* 1 or 2 in each cell, suspended; *style* simple; *stigma* 5-lobed. *Fruit* drupaceous, 5-celled, or fewer-celled by

abortion. *Seeds* orthotropous, with a narrow embryo lying in fleshy albumen.

Distribution and Numbers.—Natives of tropical America. *Illustrative Genera:*—Humirium, *Mart.*, Vantanea, *Aubl.* There are 18 species.

Properties and Uses.—A balsamic yellow oily liquid, called Balsam of Umiri, is obtained from the incised stem of *Humirium floribundum*; this is reputed to resemble Copaiba in its properties. The bark is used by the Brazilians as a perfume.

Order 87. MALPIGHIACEÆ, the Malpighia Order.—Character.—*Trees* or *shrubs*, often climbing. *Leaves* usually opposite or whorled, rarely alternate; *stipules* generally short and deciduous, sometimes large and interpetiolar; the leaves are occasionally furnished with peltate hairs. *Flowers* perfect or polygamous. *Calyx* 5-partite, persistent, frequently with glands at the base of one or all of the divisions; *æstivation* imbricate or rarely valvate. *Petals* 5, hypogynous, unguiculate; *æstivation* convolute. *Stamens* usually 10, monadelphous or distinct; *connective* fleshy and elongated beyond the anther lobes. *Ovary* generally consisting of 3 carpels, rarely 2 or 4, partially or wholly combined; *ovules* 1 in each cell, pendulous from a long stalk; *styles* 3, distinct or united; *stigmas* 3, simple. *Fruit* either drupaceous, samaroid, or a woody nut. *Seed* solitary, exalbuminous; *embryo* straight or variously curved.

Diagnosis.—Trees or shrubs, with simple stipulate leaves. Flowers perfect or polygamous. Calyx and corolla with 5 parts; the sepals having usually large glands at the base, and imbricate or very rarely valvate in æstivation; the petals unguiculate, without appendages, hypogynous, convolute. Stamens usually 10, sometimes 15, with a fleshy prolonged connective. Ovary generally composed of 3 carpels, or in any case not corresponding in number to, or being any power of, the three outer whorls; ovules solitary, pendulous from long stalks. Seeds exalbuminous, usually with a convolute embryo.

Distribution and Numbers.—They are almost exclusively natives of tropical regions. *Illustrative Genera:*—Malpighia, *Plum.*; Byrsonima, *Rich.*; Nitraria. There are about 580 species.

Properties and Uses.—An astringent property appears to be most general in the plants of this order. Some have edible fruits, and the seeds of others are reputed to be poisonous.

Order 88. ZYGOPHYLLACEÆ, the Bean-caper or Guaiacum Order.—Character.—*Herbs*, *shrubs*, or *trees*. *Leaves* opposite,

stipulate, without dots, usually imparipinnate, or rarely simple. *Flowers* perfect, regular, and symmetrical. *Calyx* 4- or 5-partite, convolute. *Petals* unguiculate, 4 or 5, imbricate, hypogynous. *Stamens* 8—10, hypogynous, usually arising from the back of small scales; *filaments* dilated at the base. *Ovary* 4—5-celled, surrounded by glands or a *toothed disc*; *style* simple; *ovules* 2 or more in each cell; *placentas* axile. *Fruit* capsular, dehiscing in a loculicidal manner, or separating into cocci, 4- or 5-celled, and presenting externally as many angles or winged expansions as cells; rarely indehiscent. *Seeds* few; *albumen* in small quantity, or rarely absent; *radicle* superior; *cotyledons* foliaceous.

Diagnosis.—Herbs, shrubs, or trees, with opposite stipulate dotless leaves. Calyx and corolla with a quaternary or quinary arrangement; the former convolute in æstivation, the latter with unguiculate petals and imbricate. Stamens 8—10, hypogynous, usually arising from the back of scales. Ovary 4—5-celled; style simple. Fruit 4- or 5-celled. Seeds few, with little or no albumen; radicle superior; cotyledons foliaceous.

Distribution and Numbers.—They are generally distributed throughout the warm regions of the globe, but chiefly beyond the tropics. *Illustrative Genera:*—Zygophyllum, *Linn.*; Guaiacum, *Plum.* There are about 100 species. *Melianthus* is by some botanists separated from the Zygophyllaceæ, and taken as the type of a new order, to which the name *Melianthecæ* has been applied.

Properties and Uses.—Some of the plants are resinous, and possess stimulant, alterative, and diaphoretic properties; others are anthelmintic. The wood of the arborescent species is remarkable for its hardness and durability.

Order 89. Geraniaceæ, the Crane's-bill Order.—Character.—*Herbs* or *shrubs*, with swollen, usually articulated nodes. *Leaves* simple, opposite or alternate, with membranous stipules. *Flowers* regular or irregular. *Sepals* 5, inferior, persistent, more or less unequal; *æstivation* imbricate. *Petals* 5, or rarely 4 from abortion, unguiculate, hypogynous or perigynous; *æstivation* twisted. *Stamens* usually twice as many as the petals (some are, however, frequently abortive), hypogynous, and generally united at the base, the alternate ones shorter and occasionally barren. *Disc* inconspicuous or glandular. *Carpels* 5, arranged around an elongated axis or carpophore; *styles* corresponding in number to the carpels, and adhering to the carpophore. *Fruit* consisting of five 1-seeded carpels, which

ultimately separate from the carpophore from below upwards by the curling up of the styles, which remain adherent at the summit. *Seeds* without albumen; *cotyledons* foliaceous, convolute.

Diagnosis.—Herbs or shrubs, with simple leaves, membranous stipules, and swollen nodes. Sepals 5, imbricate. Petals twisted in æstivation. Stamens hypogynous, generally united at the base. Fruit consisting of 5 carpels attached by means of their styles to an elongated axis or carpophore, from which they separate when ripe from below upwards by the curling up of the styles. Seeds 1 in each carpel, exalbuminous; embryo with foliaceous convolute cotyledons.

Fig. 1076.

Fig. 1077.

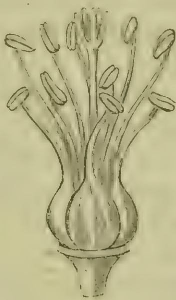


Fig. 1078.

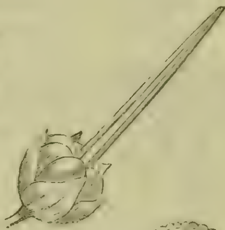


Fig. 1079.

Fig. 1076. A portion of the flowering stem of *Geranium sylvaticum.*——*Fig.* 1077. The andrœcium and gynœcium of the same.——*Fig.* 1078. The pistil, partially matured, surrounded by the persistent calyx.——*Fig.* 1079. Transverse section of the seed.

Distribution and Numbers.—Some are distributed over various parts of the world, but they abound at the Cape of Good Hope. *Examples of the Genera:*—Erodium, *L'Héritier*; Geranium, *Linn.*; Pelargonium, *L'Héritier*. There are nearly 550 species.

Properties and Uses.—Astringent, resinous, and aromatic qualities are the more important properties of the plants of this order. Many are remarkable for the beauty of their flowers, and others for the agreeable odours of their leaves and flowers, which render them useful in perfumery.

Order 90. Balsaminaceæ, the Balsam Order.—Character. *Herbaceous plants* with succulent *stems* and a watery juice. *Leaves* alternate or opposite, simple, exstipulate. *Flowers*

hypogynous, very irregular *Sepals* 3--5, very irregular, deciduous, with an imbricate æstivation, the odd one spurred. *Petals* 5, or more usually 4, 1 being abortive: distinct or irregularly united, deciduous, alternate with the sepals; *æstivation* convolute. *Stamens* 5, alternate with the petals, and somewhat united. *Disc* none. *Ovary* composed of 5 carpels, united so as to form a 5-celled compound body; *style* simple; *stigma* more or less divided into 5 lobes. *Fruit* usually capsular, 5-celled, and dehiscing in a septifragal manner by 5 elastic valves, which become coiled up; sometimes succulent and indehiscent; *placentas* axile. *Seeds* solitary or numerous, suspended, exalbuminous; *embryo* straight.

Diagnosis.—Succulent herbaceous plants, with simple exstipulate leaves. Stems continuous and not separable at the nodes. Flowers hypogynous, very irregular. Sepals 3—5; petals usually 4; both irregular and deciduous; æstivation of sepals imbricate, that of the petals convolute. Stamens 5. Ovary 5-celled; style simple. Fruit 5-celled, usually bursting with elasticity, without a beak. Seeds suspended, exalbuminous. *This order is included by Bentham and Hooker in Geraniaceæ.*

Fig. 1080.

Fig. 1080. Capsule of Touch-me-not (*Impatiens noli-me-tangere*), with recurved coiled-up valves.

Distribution and Numbers.—A few are scattered over the globe; but they are chiefly natives of the Indies, growing generally in damp shady places and where the temperature is moderate. *Illustrative Genus*:—Impatiens, *Linn.* There are about 110 species.

Properties and Uses.—They are said by De Candolle to be diuretic, but their properties are generally unimportant.

Order 91. VIVIANIACEÆ, the Viviania Order.—*Diagnosis.* These plants are readily known among the Disciforæ by their exstipulate leaves, regular flowers, valvate 10-ribbed calyx, permanent withering twisted petals, 10 hypogynous stamens with distinct filaments, 2-celled anthers with longitudinal dehiscence, superior 3-celled ovary, 3-celled capsule with loculicidal dehiscence, and albuminous seeds with a curved embryo and radicle next the hilum. *This order is included by Bentham and Hooker in Geraniaceæ.*

Distribution and Numbers.—They inhabit Chili and South

Brazil. *Illustrative Genera:*—Cæsarea, *Cambess.*; Viviania, *Willd.* There are 15 species.

Properties and Uses.—Unimportant.

Order 92. Tropæolaceæ, the Indian Cress Order.—Character.—Smooth twining or trailing herbaceous plants, with an acrid juice. *Leaves* alternate, exstipulate. *Flowers* irregular. *Sepals* 3—5, the upper one spurred; valvate or very slightly imbricate in æstivation. *Petals* 3—5, hypogynous, more or less unequal; *æstivation* convolute. *Stamens* 6—10, somewhat perigynous, distinct; *anthers* 2-celled. *Disc* none. *Ovary* of 3 or 5 carpels, each of which contains one pendulous ovule; *style* 1; *stigmas* 3 or 5. *Fruit* indehiscent, usually consisting of 3 carpels arranged round a common axis, from which they ultimately separate, each carpel containing one seed. *Seed* large, exalbuminous; *embryo* large; *radicle* next the hilum. *This order is included in Geraniaceæ by Bentham and Hooker.*

Distribution and Numbers.—Chiefly natives of South America. *Illustrative Genera:*—Tropæolum, *Linn.*; Chymocarpus, *Don.* There are about 40 species.

Properties and Uses.—Generally acrid, pungent, and antiscorbutic, resembling the Cruciferæ. The unripe fruit of *Tropæolum majus*, which is commonly known as Indian Cress, or Garden Nasturtium, is frequently pickled, and employed by housekeepers as a substitute for Capers. Most of the *Tropæolums* have tubercular roots, some of which are edible, as *T. tuberosum.*

Order 93. Limnanthaceæ, the Limnanthes Order.—*Diagnosis.*—This is a small order of plants included by Lindley in the Tropæolaceæ, with which it agrees in its general characters; but it is distinguished from that order by having regular flowers, more evidently perigynous stamens, and erect ovules. *It is placed in Geraniaceæ by Bentham and Hooker.*

Distribution and Numbers.—Natives of North America. *Illustrative Genus:*—Limnanthes, *R. Br.* There are 3 species.

Properties and Uses.—In these they resemble the Cruciferæ and Tropæolaceæ.

Order 94. Oxalidaceæ, the Wood-sorrel Order.—Character.—*Herbs*, or rarely *shrubs* or *trees*, generally with an acid juice. *Leaves* alternate or rarely opposite, usually compound or occasionally simple, generally with stipules, or rarely exstipulate. *Flowers* regular and symmetrical. *Sepals* 5, persistent, imbricate, occasionally somewhat united at their base. *Petals* 5,

hypogynous, unguiculate, rarely wanting; *æstivation* twisted. *Stamens* double the number of the petals and sepals, arranged in two rows alternating with each other, the inner row longer than the outer and opposite to the petals, commonly somewhat monadelphous; *anthers* 2-celled, innate. *Disc* none. *Ovary* superior, 3—5-celled, with as many distinct styles as there are cells; *stigmas* capitate or somewhat bifid. *Fruit* usually capsular and 3—5-celled and 5—10-valved, occasionally drupaceous and indehiscent; *placentas* axile. *Seeds* few; sometimes provided with a fleshy integument, which bursts with elasticity when the fruit is ripe, and expels the seeds; *embryo* straight, in cartilaginous fleshy albumen; *radicle* long, and turned towards the hilum; *cotyledons* flat.

Diagnosis.—Herbs, or rarely shrubs or trees, usually with

FIG. 1081.

FIG. 1082.

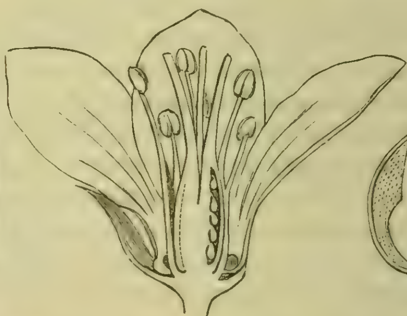


FIG. 1083.

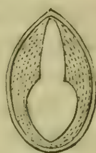


Fig. 1081. Diagram of the flower of *Oxalis.*——*Fig.* 1082. Vertical section of the flower of the same.——*Fig.* 1083. Vertical section of the seed.

compound exstipulate leaves. Stems continuous and not separable at the nodes. Flowers hypogynous, regular, symmetrical. Sepals, petals, and stamens with a quinary distribution; the sepals persistent and imbricate; the petals twisted in æstivation; the stamens commonly somewhat monadelphous, with 2-celled innate anthers. Disc absent. Styles filiform, distinct. Fruit 3—5-celled, without a beak. Seeds few, with abundant albumen, a straight embryo, long radicle turned towards the hilum, and flat cotyledons. *This order is closely allied to the Geraniaceæ, to which it is referred by Bentham and Hooker.*

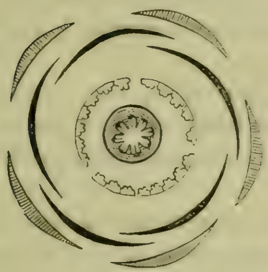
Distribution and Numbers.—These plants are generally distributed throughout both the hot and temperate regions of the globe; the shrubby species are, however, confined to the former. They are most abundant at the Cape of Good Hope and in

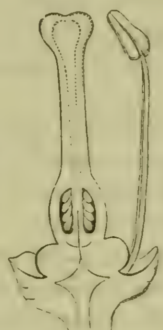
tropical America. *Illustrative Genera:*—Oxalis, *Linn.*; Averrhoa, *Linn.* There are about 330 species.

Properties and Uses.—Chiefly remarkable for their acid juice, which is due to the presence of binoxalate of potassium. The fruits of some are eaten by the natives in the East Indies, but they are too acid to be generally acceptable to Europeans.

Order 95. RUTACEÆ, the Rue Order.—Character.—*Trees*, *shrubs*, or rarely *herbs*. *Leaves* exstipulate, simple or compound, dotted. *Flowers* perfect or polygamous, regular. *Calyx* having 3—5 segments, imbricate. *Petals* equal in number to the divisions of the calyx or wanting, rarely combined so as to form a gamopetalous corolla; *æstivation* usually twisted, rarely valvate.

Fig. 1084. Fig. 1085. Fig. 1086. Fig. 1087.





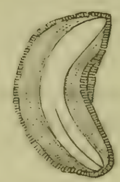


Fig. 1084. Diagram of the flower of the Orange (*Citrus Aurantium*).——*Fig.* 1085. Vertical section of the pistil, showing a portion of the disc at its base, and a solitary hypogynous stamen.——*Fig.* 1086. Pistil of the Orange, with disc at its base, and the calyx: the petals and stamens have been removed.——*Fig.* 1087. Vertical section of the seed of the Common Rue (*Ruta graveolens*).

Stamens distinct, or more or less united into one or several bundles, equal in number to or twice as many as the petals, or some multiple of them, or rarely fewer by abortion. *Disc* annular or cup-shaped, glandular, hypogynous. *Ovary* sessile, or raised on a gynophore; it is composed of from 2 to 5 carpels, which are either distinct or united so as to form a compound ovary having as many cells as there are component carpels; *style* simple or divided towards the base; *ovules* 2, 4, or rarely more in each cell. *Fruit* capsular, its carpels either united or more or less distinct, or succulent and indehiscent, and in *Aurantieæ* forming a hesperidium. *Seeds* solitary or in pairs; *albumen* present or absent; *radicle* superior.

Diagnosis.—Leaves exstipulate, dotted. Flowers perfect

or polygamous. Calyx and corolla with a ternary, quaternary, or quinary distribution of their parts; the former with an imbricate æstivation, the latter twisted or valvate, and sometimes wanting. Stamens equal in number to or twice as many as the petals, or some multiple of them, or fewer. Ovary of from 2 to 5 carpels, separate or combined, either sessile and surrounded at the base by a fleshy and glandular disc, or elevated upon a gynophore; ovules sessile. Fruit capsular or succulent. Embryo with a superior radicle. Albumen present or absent.

Division of the Order and Illustrative Genera.—The Rutaceæ have been variously divided, and Bentham and Hooker have largely extended the order by including the orders Aurantiaceæ and Xanthoxylaceæ of former botanists, which arrangement is here adopted. As thus extended, they have divided it into the following tribes:—Cusparieæ, Ruteæ, Diosmeæ, Boronieæ, Xanthoxyleæ, Toddalieæ, and Aurantieæ. *Illustrative Genera:* Ruta, *Tourn.*; Barosma, *Willd.*; Xanthoxylon, *Kunth.*; Toddalia, *Juss.*; Citrus, *Linn.*

The Xanthoxyleæ are especially distinguished by their *polygamous flowers*; and the Aurantieæ by the blade of their leaves being articulated to the petiole, their deciduous imbricate petals, and their peculiar fruit (*hesperidium*).

Distribution and Numbers.—The Ruteæ are found chiefly in the southern part of the temperate zone and in Northern Asia; the genera *Diosma*, *Barosma*, &c., abound at the Cape of Good Hope; other genera are found in Australia, and some in equinoctial America. Xanthoxyleæ are mostly American, Aurantieæ usually East Indian. There are about 620 species.

Properties and Uses.—The Ruteæ are generally characterised by a powerful penetrating odour and bitter taste. In medicine they are employed as antispasmodics, tonics, febrifuges, diuretics, &c. The Xanthoxyleæ are almost universally characterised by pungent and aromatic properties, and sometimes by bitterness. In medicine, they have been employed as stimulants, sudorifics, febrifuges, tonics, sialogogues, and emmenagogues. The Aurantieæ abound in glands containing essential oils, which render them fragrant. These volatile oils are especially abundant in the leaves, the petals, and the rind of the fruit. The latter also contains a bitter tonic principle. The pulp of the fruit has an acid or somewhat saccharine taste; and the wood is always hard, and of a compact nature.

Order 96. SIMARUBACEÆ, the Quassia Order.—Character.—*Shrubs* or *trees*. *Leaves* without dots, alternate, compound or

sometimes simple, exstipulate. *Flowers* regular and symmetrical, axillary, or terminal, perfect, or unisexual by abortion. *Calyx* imbricate, in 4 or 5 divisions. *Petals* equal in number to the divisions of the calyx, with an imbricate æstivation, sometimes united into a tube. *Stamens* twice as many as the petals, the *filaments* usually with a scale at their back; *anthers* with longitudinal dehiscence. *Disc* conspicuous, hypogynous. *Ovary* stalked, 4- or 5-lobed, 4- or 5-celled, each cell with 1 suspended ovule; *style* simple; *stigma* with as many lobes as there are cells to the ovary. *Fruit* usually consisting of 4 or 5 indehiscent, 1-seeded, drupaceous carpels, arranged around a common axis, or capsular or samaroid. *Seeds* with a membranous integument, exalbuminous; *radicle* superior, retracted within thick cotyledons.

Distribution and Numbers.—With the exception of one plant, which is a native of Nepaul, they are all found in the tropical parts of India, America, and Africa. *Illustrative Genera*:—Quassia, *Linn.*; Simaruba, *Aubl.* There are about 50 species.

Properties and Uses.—A bitter principle is the most remarkable characteristic of the order; hence many of them are tonic and febrifugal.

Order 97. OCHNACEÆ, the Ochna Order.—Character.—*Under-shrubs* or *smooth trees*, with a watery juice. *Leaves* simple, stipulate, alternate. *Pedicels* jointed in the middle. *Sepals* 5, persistent, imbricate. *Petals* hypogynous, definite, sometimes twice as many as the sepals, deciduous, imbricate. *Stamens* equal in number to the sepals and opposite to them, or twice as many, or more numerous; *filaments* persistent, inserted on an hypogynous fleshy *disc*; *anthers* 2-celled, with longitudinal or porous dehiscence. *Carpels* sessile, corresponding in number to the petals, inserted on a large fleshy disc, which becomes larger as the carpels grow; *ovules* 1 in each carpel. *Fruit* consisting of several indehiscent, somewhat drupaceous, 1-seeded carpels. *Seeds* exalbuminous or nearly so; *embryo* straight; *radicle* towards the hilum.

Distribution and Numbers.—Natives chiefly of the tropical parts of India, Africa, and America. *Illustrative Genera*:—Gomphia, *Schreb.*; Ochna, *Schreb.* There are about 80 species.

Properties and Uses.—The plants are generally remarkable for their bitterness. Some have been employed as tonics and astringents; others, as *Gomphia parviflora*, yield oil, which is

used in Brazil for salads. In their properties generally, the Ochnaceæ much resemble the Simarubaceæ.

Order 98. BURSERACEÆ OR AMYRIDACEÆ, the Myrrh Order. Character.—*Trees* or *shrubs*, abounding in a fragrant gum-resinous or resinous juice. *Leaves* compound, alternate or opposite, frequently dotted and stipulate. *Flowers* perfect, or rarely unisexual. *Calyx* persistent, with 2—5 divisions. *Petals* 3—5, arising from the calyx below the disc; *æstivation* valvate, or occasionally imbricate. *Stamens* twice as many as the petals, perigynous. *Disc* perigynous. *Ovary* 1—5-celled, superior, sessile, placed in or upon the disc; *ovules* in pairs, attached to a placenta at the apex of the cell, anatropous. *Fruit* dry, 1—5-celled; *epicarp* often splitting in a valvular manner. *Seeds* exalbuminous; *radicle* superior, turned towards the hilum.

Distribution and Numbers.—They have been found only in the tropical regions of America, Africa, and India. *Illustrative Genera:*—Boswellia, *Roxb.*; Balsamodendron, *Kunth.* There are about 60 species.

Properties and Uses.—The plants of the order appear to be almost universally characterised by an abundance of fragrant resinous or gum-resinous juice. Some are considered poisonous; others bitter, purgative, or anthelmintic; and a few furnish useful timber.

Order 99. MELIACEÆ, the Melia Order.—Character.—*Trees* or *shrubs*. *Leaves* alternate or rarely somewhat opposite, simple or pinnate, exstipulate. *Flowers* occasionally unisexual by abortion. *Calyx* 3- 4- or 5-partite. *Petals* equal in number to the divisions of the calyx, hypogynous, sometimes united at the base; imbricate or valvate. *Stamens* twice as many as the petals, monadelphous; *anthers* sessile, placed within the orifice of the tube formed by the united filaments. *Disc* hypogynous, sometimes large and cup-like. *Ovary* compound, usually 2- 3- 4- or 5-celled, rarely 10- or 12-celled; *style* 1; *stigmas* separate or combined; *ovules* 1, 2, or rarely 4, in each cell. *Fruit* baccate, drupaceous, or capsular, in the latter case opening loculicidally; many-celled, or by abortion 1-celled. *Seeds* few, not winged, arillate or exarillate; *albumen* fleshy or usually absent; *embryo* generally with leafy cotyledons.

Diagnosis.—This order is very nearly allied to Cedrelaceæ, and by some botanists the latter order is included in it. It is chiefly distinguished from Cedrelaceæ by having more completely monadelphous stamens; by the possession of fewer seeds; and in those seeds being without wings.

Distribution and Numbers.—They are found more or less in all the tropical parts of the globe, but are said to be more common in America and Asia than in Africa. A few are extra-tropical. *Illustrative Genera* :—Melia, *Linn.*; Aglaia, *Lour.* There are about 150 species.

Properties and Uses.—These plants are generally remarkable for bitter, tonic, and astringent properties. Others are powerful purgatives and emetics, as *Guarea Aubletii*, *G. trichilioides*, *G. purgans*, *G. spiciflora*, and some species of *Trichilia*; these all require much caution in their administration, and in some cases are reputed poisonous. A few species have edible fruits. The seeds of some yield fixed oils by expression.

Order 100. CEDRELACEÆ, the Mahogany Order.—Character.—*Trees.* *Leaves* alternate, pinnate, exstipulate. *Calyx* 4—5-cleft, imbricate. *Petals* hypogynous, of the same number as the divisions of the calyx, imbricate *Stamens* twice as many as the petals and divisions of the calyx, either united below into a tube, or distinct and inserted into an annular hypogynous *disc*; *anthers* 2-celled, with longitudinal dehiscence. *Ovary* usually with as many cells as there are divisions to the calyx and corolla, or rarely only 3; *ovules* 4 or more, in two rows, anatropous; *style* and *stigma* simple. *Fruit* capsular, dehiscence usually septifragal. *Seeds* flat, winged, attached to axile placentas; *albumen* thin or none; *embryo* straight, erect, with the radicle next the hilum. *This order is now frequently incorporated with Meliaceæ.*

Distribution and Numbers.—Chiefly natives of the tropical parts of America and India; they are very rare in Africa. *Illustrative Genera* :—Swietenia, *Linn.*; Soymida, *Adr. Juss.* There are about 25 species.

Properties and Uses.—The plants of this order have fragrant, aromatic, tonic, astringent, and febrifugal properties, and many of them are valuable timber-trees.

Order 101. CHAILLETIACEÆ, the Chailletia Order.—Character.—*Trees* or *shrubs.* *Leaves* alternate, entire, stipulate. *Calyx* inferior, with 5 sepals; *æstivation* induplicate. *Stamens* 10, perigynous, in two alternate whorls, the outer petaloid and sterile; but the latter whorl more resembles a *corolla.* *Ovary* superior, 2—3-celled, with twin suspended ovules. *Fruit* dry, 1—3-celled. *Seeds* exalbuminous. This order has been variously placed, but is more commonly referred here.

Distribution and Numbers.—Natives of tropical regions.

Illustrative Genera :—Chailletia, *DC.*; Stephanopodium, *Pöpp.* There are about 10 species.

Properties and Uses.—Unimportant. The fruit of *Chailletia toxicaria*, a native of Sierra Leone, is commonly called Ratsbane on account of its poisonous nature.

Cohort 2.—*Olacales.*

Order 102. OLACACEÆ, the Olax Order.—Character.—*Trees* or *shrubs*, with alternate simple entire exstipulate leaves. *Flowers* small, regular, axillary. *Calyx* minute, gamosepalous, generally enlarging so as to cover the fruit; *æstivation* imbricate. *Petals* hypogynous, valvate in æstivation. *Stamens* definite, partly sterile and partly fertile; the latter opposite to the petals, inserted upon or outside of a conspicuous *disc*; *anthers* 2-celled, bursting longitudinally. *Ovary* free, often imbedded in the disc; *ovules* suspended from a free central placenta. *Fruit* drupaceous. *Seed* without integuments, solitary; *embryo* minute; *albumen* fleshy.

Distribution and Numbers.—Natives of tropical or subtropical regions. *Illustrative Genera* :—Olax, *Linn.*; Liriosma, *Pöpp.* The number of species is doubtful.

Properties and Uses.—Some have fragrant flowers. The fruit of *Ximenia americana* is eaten in Senegal. The leaves of *Olax zeylanica* are used by the Cingalese in their curries, &c., and the wood in putrid fevers. The wood of *Heisteria coccinea* is considered by some to furnish the Partridge-wood of cabinetmakers.

Order 103. ICACINACEÆ, the Icacina Order.—*Diagnosis.*—This is an order of plants consisting of evergreen trees and shrubs, and formerly included in the order Olacaceæ; but, as shown by Miers, they are clearly distinguished from that order, as follows: 'They differ most essentially in the *calyx* being always small, persistent, and unchanged, and never increasing with the growth of the fruit; the *stamens* being always alternate with the petals, not opposite; the *petals* and *stamens* are never fixed on the margin of the *conspicuous cup-shaped disc*; the *ovary* is normally plurilocular with axile placentation, and when unilocular, this happens only from the abortion of the other cells, the traces of which are always discernible, never completely unilocular at the summit, and plurilocular at base, with free central placentation. In Icacinaceæ the *ovules* are suspended below the summit of the cell in pairs superimposed by

cup-shaped podosperms; only one of these becomes perfected, and the *seed* is furnished with the usual integuments.'

Distribution and Numbers.—'They are natives of tropical or sub-tropical countries; chiefly the East Indies, Africa, and South America, a single species being found each in New Holland, Norfolk Island, and New Zealand.' *Illustrative Genera:*—Icacina, *Adr. Juss.*; Sarcostigma, *W. et A.* There are about 70 species.

Properties and Uses.—Unknown.

Order 104. CYRILLACEÆ, the Cyrilla Order.—*Diagnosis.*—Evergreen shrubs, with alternate exstipulate leaves, nearly related to *Olacaceæ*, but chiefly distinguished by their imbricate petals, which are altogether free from any hairiness on their inside; and by the stamens being all fertile, and, if equal in number to the petals, alternate with them.

Distribution and Numbers.—They are all natives of North or Tropical America. *Illustrative Genera:*—Cyrilla, Mylocaryum. There are 6 species.

Properties and Uses.—Unknown.

Order 105. PHYTOCRENACEÆ, the Phytocrene Order.—*Diagnosis.*—This order has been variously placed by botanists, *but is referred here by Bentham and Hooker.* Formerly it was incorporated with the Artocarpaceæ, but their seeds have a large quantity of albumen, which at once distinguishes them from that order. The plants comprised in it, all of which belong to the genus Phytocrene, *Wall.*, are climbing shrubs, natives of the East Indies, with dichlamydeous unisexual flowers, and seeds with a large quantity of albumen. Their wood has also a very peculiar structure. They yield a large quantity of watery juice when wounded; hence they are termed Water-vines, or 'Plant-fountains.' In Martaban this juice is drunk by the natives.

Order 106. AQUIFOLIACEÆ OR ILICACEÆ, the Holly Order.—Character.—Evergreen *trees* or *shrubs*. *Leaves* coriaceous, simple, exstipulate or with minute stipules. *Flowers* small, axillary, sometimes unisexual. *Sepals* distinct, 4—6, imbricate. *Corolla* 4—6-partite, imbricate. *Stamens* equal in number to the divisions of the corolla and alternate with its segments; *anthers* 2-celled, adnate, opening longitudinally. *Disc* none. *Ovary* superior, 2—6- or more-celled, with one suspended ovule in each cell; *placentas* axile. *Fruit* fleshy, indehiscent. *Seed* suspended; *embryo* small, at the base of a large quantity of fleshy albumen; *radicle* superior.

Distribution and Numbers.—They are widely although

sparingly scattered over the globe. Only one species, the common Holly, is found in Europe. *Illustrative Genera* :—Ilex, *Linn.*; Prinos, *Linn.* There are about 115 species.

Properties and Uses.—Bitter, tonic, and astringent properties are those chiefly found in the plants of this order. Some are emetic and purgative, while others are largely used as a kind of Tea.

Cohort 3.—*Celastrales.*

Order 107. CELASTRACEÆ, the Spindle-tree Order.—Character.—*Shrubs* or *small trees*. *Leaves* simple, generally alternate, or rarely opposite, with small deciduous stipules. *Sepals* 4—5, imbricate. *Petals* with imbricate æstivation, equal in number to the sepals, inserted on a large disc; sometimes wanting. *Stamens* as many as the petals and alternate with them, inserted on the disc; *anthers* innate. *Disc* large, flat, expanded. *Ovary* sessile, superior, surrounded by the disc, 2—5-celled, each cell with 2 ovules; *ovules* erect, with a short stalk. *Fruit* superior, 2—5-celled, either drupaceous and indehiscent, or capsular with loculicidal dehiscence. *Seeds* with or without an aril; *albumen* fleshy; *embryo* straight; *radicle* short, inferior; *cotyledons* flat.

Diagnosis.—Shrubby plants, with simple leaves and small deciduous stipules. Flowers small, regular, and perfect; or rarely unisexual by abortion. Sepals and petals 4—5, imbricate in æstivation. Stamens equal in number to, and alternate with, the petals, and inserted with them on a large flat expanded disc. Ovary superior, sessile, surrounded by the disc. Fruit superior, 2—5-celled. Seeds albuminous; embryo straight; radicle inferior.

Distribution and Numbers.—Chiefly natives of the warmer parts of Asia, North America, and Europe; they are also plentiful at the Cape of Good Hope. Generally speaking, the plants of the order are far more abundant out of the tropics than in them. *Illustrative Genera* :—Euonymus, *Linn.*; Celastrus, *Kunth.* There are about 280 species.

Properties and Uses.—Chiefly remarkable for the presence of an acrid principle. The seeds of some contain oil.

Order 108. HIPPOCRATEACEÆ, the Hippocratea Order.—Character.—*Shrubs*, with opposite simple leaves, and small deciduous stipules. *Flowers* small, regular, and unsymmetrical. *Sepals* and *petals* 5, hypogynous, imbricate, the former persistent. *Stamens* 3, hypogynous, monadelphous; *anthers* with

transverse dehiscence. *Disc* conspicuous. *Ovary* 3-celled; *placentas* axile; *style* 1. *Fruit* baccate, or consisting of 3 samaroid carpels. *Seeds* definite, exalbuminous; *embryo* straight; *radicle* inferior. *This order is referred to Celastraceæ by Bentham and Hooker.*

Distribution and Numbers.—They abound principally in South America; some are found also in Africa and the East Indies. *Illustrative Genera*:—Hippocratea, *Linn.*; Tontelea, *Aubl.* There are about 86 species.

Properties and Uses.—Very little is known generally of the plants of this order. The fruit of several Brazilian species of *Tontelea* is edible, and in Sierra Leone that of *T. pyriformis* is described as very pleasant. *Hippocratea comosa* yields nuts of an oily and sweet nature. The inner yellow bark of *Kokoona zeylanica* is employed in Ceylon as a febrifuge and sternutatory, and as a dye.

Order 109. STACKHOUSIACEÆ, the Stackhousia Order.—Character.—*Herbs* or rarely *shrubs*, with simple, entire, alternate, minutely stipulate leaves. *Calyx* 5-cleft, with its tube inflated. *Petals* 5, united below into a tube, arising from the top of the tube of the calyx, and having a narrow stellate limb. *Stamens* 5, distinct, of unequal length, perigynous. *Ovary* superior, 3- or 5-celled, each cell containing one erect ovule; *styles* 3 or 5. distinct or united at the base. *Fruit* consisting of from 3 to 5 indehiscent carpels, attached to a central persistent column. *Seeds* with fleshy albumen; *embryo* erect; *radicle* inferior.

Distribution and Numbers.—Natives of Australia. *Illustrative Genera*:—Stackhousia, *Smith*; Tripterococcus, *Endl.* There are about 20 species.

Properties and Uses.—Unknown.

Order 110. RHAMNACEÆ, the Buckthorn Order.—Character. *Shrubs* or *small trees*, which are often spiny. *Leaves* simple, alternate or rarely opposite; *stipules* small or wanting. *Flowers* small, usually perfect or sometimes unisexual. *Calyx* 4—5-cleft, with a valvate æstivation. *Disc* fleshy, lining the tube of the calyx. *Petals* equal in number to the divisions of the calyx, and inserted into its throat, hooded or convolute, sometimes wanting. *Stamens* perigynous, equal in number to the petals and opposite to them, or alternate with the divisions of the calyx when the petals are wanting. *Ovary* superior or half superior, immersed in the disc, 2- 3- or 4-celled; *ovules* one in each cell, erect. *Fruit* dry and capsular, or fleshy and indehiscent. *Seeds* one in each cell, erect, usually with fleshy albumen, but this is

sometimes wanting, exarillate; *embryo* long, with a short inferior radicle, and large flat cotyledons.

Diagnosis.—Small trees or shrubs, with simple leaves and small regular usually perfect flowers; rarely unisexual. Calyx 4—5-parted, valvate, with the tube coated with a disc. Petals and stamens distinct, perigynous, and equal in number to the divisions of the calyx; the petals sometimes wanting, but, when present, opposite to the stamens. Ovary more or less superior, surrounded by a fleshy disc. Fruit 2- 3- or 4-celled, with one erect seed in each cell. Seed usually albuminous, without an aril.

Distribution and Numbers.—Generally distributed over the globe except in the very coldest regions. *Illustrative Genera:*——Zizyphus, *Tourn.*; Rhamnus, *Juss.* There are about 400 species.

Properties and Uses.—Some of the plants have acrid and purgative properties; others are bitter, febrifugal, and tonic. A few are used in the preparation of dyeing materials, and some few others have edible fruits.

Order 111. VITACEÆ, the Vine Order.—Character.—Usually *shrubs*, with a watery juice, climbing by tendrils, the young nodes swollen. *Leaves* simple or compound, opposite below, alternate above, stipulate or exstipulate. *Flowers* regular, small, green, stalked. *Calyx* minute, with the limb generally obsolete. *Petals* 4 or 5, sometimes united at the base; inserted *on a disc* which surrounds the ovary, caducous; *æstivation* induplicate. *Stamens* corresponding in number to the petals and opposite to them, also inserted on the disc; *filaments* distinct or somewhat united at the base; *anthers* versatile, bursting longitudinally. *Ovary* superior, surrounded by a disc; usually 2-celled; *style* very short, simple; *stigma* simple. *Fruit* succulent, sometimes termed a nuculanium, usually 2-celled. *Seeds* erect, few, usually 2 in each cell; *testa* bony; *albumen* hard; *embryo* erect, with an inferior radicle.

Diagnosis.—Shrubby plants, climbing by tendrils, with simple or compound leaves, which are opposite below and alternate above. Flowers small, green, regular. Petals and stamens corresponding in number, 4 or 5, the latter opposite to the petals, both inserted on an hypogynous disc; æstivation of petals induplicate; anthers versatile, opening longitudinally. Ovary superior, surrounded by a disc, with a very short simple style and stigma. Fruit baccate. Seeds few; testa bony; embryo erect in horny albumen; radicle inferior.

Distribution and Numbers.—The plants of this order are found in warm and tropical regions of the globe. None are natives of Europe. The common Grape Vine, which is now completely naturalised in the South of Europe, and is cultivated nearly all over the globe where the temperature does not rise too high or fall too low, is supposed to be a native of the shores of the Caspian. *Illustrative Genera* :—Vitis, *Linn.*; Ampelopsis, *L. C. Rich.* There are about 260 species.

Properties and Uses.—The leaves, stems, and especially the unripe fruits of the plants of this order, abound more or less in an acid juice, the acidity being chiefly due to the presence of tartaric and malic acids and acid tartrate of potash. As the fruit ripens, it generally loses its acidity, and becomes sweet, owing to the formation of sugar.

Cohort 4.—*Sapindales.*

Order 112. SAPINDACEÆ, the Soapwort Order.—Character. Usually large *trees* or twining *shrubs*, or rarely climbing *herbs*. *Leaves* generally compound, or rarely simple, alternate or sometimes opposite, often dotted, stipulate or exstipulate. *Flowers* mostly perfect and unsymmetrical, sometimes polygamous. *Sepals* 4—5, either distinct or united at the base, imbricate.

FIG. 1088.

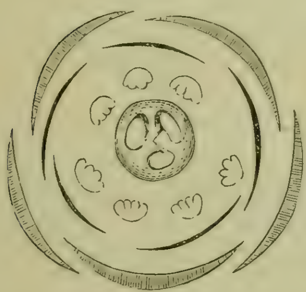


FIG. 1089.

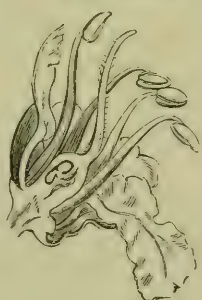


FIG. 1090.

Fig. 1088. Diagram of the flower of the Horsechestnut (*Æsculus Hippocastanum*).——*Fig.* 1089. Vertical section of the flower.——*Fig.* 1090. Vertical section of the seed.

Petals 4—5, rarely 0, hypogynous, alternate with the sepals, imbricate, naked or furnished with an appendage on the inside. *Stamens* 8—10, rarely 5—6—7, or very rarely 20, inserted into the disc or into the thalamus; *filaments* distinct or slightly monadelphous; *anthers* introrse, bursting longitudinally. *Disc* fleshy or glandular, hypogynous or perigynous. *Ovary* usually

3-celled, rarely 2- or 4-celled, each cell containing 1, 2, 3, or rarely more ovules; *style* undivided or 2—3-cleft. *Fruit* either fleshy and indehiscent; or capsular, with 2—3 valves. *Seeds* usually arillate, exalbuminous; *embryo* rarely straight, usually curved or twisted in a spiral direction; *cotyledons* sometimes very large; *radicle* next the hilum.

Diagnosis.——Flowers unsymmetrical, hypogynous. Sepals and petals 4—5, imbricate, the latter commonly with an appendage. Stamens never agreeing in number with the sepals and petals, inserted on a fleshy or glandular disc, or upon the thalamus; anthers bursting longitudinally. Fruit usually consisting of 3 carpels. Seeds commonly 2, sometimes 1 or 3, or very rarely more, exalbuminous, usually arillate and without wings; embryo almost always curved or spirally twisted.

Division of the Order and Illustrative Genera:—This order has been divided by Lindley into 4 sub-orders as follows:—

Sub-order 1. *Sapindeæ.*—Leaves alternate. Ovules usually solitary. Embryo generally curved or sometimes straight. *Illustrative Genera:*—Sapindus, *Linn.*; Nephelium, *Linn.*

Sub-order 2. *Hippocastaneæ.*—Leaves opposite. Ovules 2 in a cell, of which one is ascending, and the other suspended. Embryo curved, with a small radicle and large fleshy consolidated cotyledons. *Illustrative Genus:*—Æsculus, *Linn.*

Sub-order 3. *Dodoneæ.*—Leaves alternate. Ovules 2 or 3 in a cell. Embryo spiral. *Illustrative Genera:*—Dodonæa, *Linn.*; Ophiocaryon, *Schomb.*

Sub-order 4. *Meliosmeæ.*—Leaves alternate. Flowers very irregular. Stamens 5, 3 of which are abortive, and only 2, therefore, fertile. Ovules 2 in each cell, suspended. Fruit drupaceous. Embryo folded up. *Illustrative Genus:*—Meliosma, *Blume. Bentham and Hooker include the Meliosmeæ in the order Sabiaceæ.*

Distribution and Numbers.—Chiefly found in tropical regions, especially those of South America and India; some occur in temperate climates, but none inhabit the cold northern parts of the globe. There are no native plants of this order in Europe. The Horsechestnut, now so well known in this country, is only naturalised among us. There are nearly 400 species.

Properties and Uses.—One of the most prominent characteristics of the plants of this order is the presence of a saponaceous

principle, from which its common name is derived. Many are poisonous in all their parts; but it is more frequently the case that, while the root, leaves, and branches are dangerous, the fruits are innocuous, or even palatable. It sometimes happens, as in the Litchi and Longan fruits, that while the pericarp is wholesome, the seeds are dangerous. Some plants of the order are astringent and aromatic; others are diaphoretic, diuretic, and aperient; and some are valuable timber trees.

Order 113. ACERACEÆ, the Maple Order.—Character.—*Trees. Leaves* opposite, simple, without stipules; *venation* usually radiate, rarely pinnate. *Flowers* often polygamous, racemose or corymbose, regular. *Calyx* with an imbricate æstivation, usually 5-partite, occasionally 4- or 9-partite. *Petals* imbricate, without appendages at their base; corresponding in number to the divisions of the calyx, or altogether absent. *Stamens* usually 8, inserted on a *fleshy hypogynous disc*, or rarely the disc is absent. *Ovary* superior, 2-lobed, 2-celled; *stigmas* 2; *ovules* in pairs. *Fruit* a samara, 2-celled. *Seeds* 1 or 2 in each cell, ascending, without an aril, exalbuminous; *embryo* curved, with leafy wrinkled *cotyledons*, and an inferior *radicle. This order is placed by Bentham and Hooker in Sapindaceæ, tribe Acerineæ.*

Diagnosis.—Trees with opposite simple exstipulate leaves. Flowers often polygamous, and usually regular. Sepals and petals imbricate, the latter without any appendages on their inside. Stamens hypogynous, usually on a fleshy disc; anthers bursting longitudinally; ovary superior, 2-celled. Fruit a samara, 2-celled, each cell containing 1 or 2 seeds. Seeds ascending, without an aril, exalbuminous; embryo curved, with an inferior radicle.

Distribution and Numbers.—The plants of this order are natives of the temperate parts of Europe, Asia, and North America. None have been found in Africa and the southern hemisphere. *Illustrative Genera:*—Acer, *Linn.*; Negundo, *Mönch.* There are about 50 species.

Properties and Uses.—These plants are chiefly remarkable for their saccharine sap. Their light and handsome timber is also much used for certain parts of musical instruments; their bark is astringent, and is employed in different districts by the dyer in the production of yellow, reddish-brown, and blue colours.

Order 114.—STAPHYLEACEÆ, the Bladder-nut Order.—Character.—*Shrubs*, with opposite or rarely alternate pinnate leaves, which are furnished with deciduous stipules and stipels.

Flowers symmetrical. *Calyx* 5-partite, coloured, imbricate. *Petals* 5, alternate with the divisions of the calyx, imbricate. *Stamens* 5, alternate with the petals, and inserted with them on a large *disc*. *Ovary* superior, composed of 2 or 3 carpels, which are more or less distinct; *ovules* numerous; *styles* 2 or 3, united at the base. *Fruit* fleshy or membranous. *Seeds* ascending, with a bony testa; *embryo* straight; *albumen* little or none. *This order is now frequently placed in Sapindaceæ.*

Distribution and Numbers.—They are scattered irregularly over the globe. *Illustrative Genus*:—Staphylea, *Linn.* There are about 14 species.

Properties and Uses.—The bark of some species is bitter and astringent, as that of *Euscaphis staphyleoides*. Others have oily and somewhat purgative seeds, as *Staphylea pinnata*, &c.

Order 115. SABIACEÆ, the Sabia Order.—*Diagnosis.*—This is a small order of plants, containing only 9 species, forming 2 genera which were formerly placed as doubtful genera of the Anacardiaceæ; but the Sabiaceæ differ essentially from the Anarcardiaceæ, in their stamens being opposite to the petals; in their distinct carpels; and in their solitary ovules being directly attached to the ventral suture. Miers and Blume regard the Sabiaceæ as related to Menispermaceæ and Lardizabalaceæ. *Bentham and Hooker include the Meliosmeæ of the Sapindaceæ in this order.*

Distribution, Properties, and Uses.—Natives of the East Indies. Their properties are altogether unknown.

Order 116. ANACARDIACEÆ, the Cashew-nut Order.—Character.—*Trees* or *shrubs*, with alternate, simple or compound, dotless, exstipulate leaves, and a milky acrid or resinous juice. *Flowers* regular, small, and frequently unisexual. *Calyx* persistent, with usually 5, or sometimes 3, 4, or 7 lobes. *Petals* equal in number to the divisions of the calyx, perigynous, imbricate; sometimes absent. *Stamens* alternate with the petals, and of the same number, or twice as many, or even more numerous; perigynous, and united at the base if there is no disc, but if this is present then distinct and inserted

FIG. 1091.

Fig. 1091. Flowering branch of the *Rhus Cotinus*, or Wig-tree, with one branch bearing fruit, and the others covered with hair-like appendages and sterile.

upon it. *Disc* annular and hypogynous, or wanting. *Ovary* usually single, 1-celled, generally superior, or very rarely inferior; *styles* 1, 3, 4, or none; *stigmas* the same number as the styles; *ovules* solitary, attached to a long funiculus which arises from the base of the cell. *Fruit* indehiscent, drupaceous, or nut-like. *Seeds* without albumen.

Distribution and Numbers.—The plants of this order are chiefly found in the tropical regions of the globe, although a few are found in the South of Europe and in other extra-tropical warm districts. *Illustrative Genera:*—Pistacia, *Linn.*; Anacardium, *Rottb.* There are about 110 species.

Properties and Uses.—They abound in a resinous, somewhat gummy, acrid, or milky juice, which is occasionally very poisonous; they sometimes become black in drying. The fruits and seeds of some species are, however, held in high estimation, and are largely eaten in different parts of the world. Many plants of this order furnish varnishes.

Anomalous Orders.

Order 117. CORIARIACEÆ, the Coriaria Order.—*Diagnosis.*—Its affinities are by no means understood; but it appears to be most nearly related to Ochnaceæ, with which it agrees in having its carpels distinct and placed on an enlarged disc; but it is distinguished from that order by having opposite leaves; sometimes polygamous flowers; persistent fleshy petals; no style; and long linear distinct stigmas.

Distribution.—This order includes but 1 genus and 8 species. They are natives of the South of Europe, Chili, Peru, New Zealand, and Nepaul.

Properties and Uses.—The plants of this order are generally to be regarded with suspicion, as they have sometimes produced poisonous effects. The fruits of some, however, are edible, as *Coriaria nepalensis*, a native of the north of India, and those of *C. sarmentosa*, a native of New Zealand; in the latter case the pericarp is alone eaten, the seeds being poisonous. The fruits of *C. myrtifolia* and *C. ruscifolia* are very poisonous; these plants have been employed by dyers in the production of a black dye.

Order 118. MORINGACEÆ, the Ben-nut Order.—Character. *Trees* with bi- or tri-pinnate leaves, and thin deciduous stipules. *Flowers* white, irregular. *Sepals* and *petals* 5 each; the former deciduous and petaloid, the calyx lined by a *fleshy disc; æstivation* imbricate. *Stamens* 8 or 10, placed on the disc lining the

tube of the calyx in two whorls, the outer of which is sometimes sterile; *anthers* 1-celled. *Ovary* stalked, superior, 1-celled, with 3 parietal placentas. *Fruit* long, pod-shaped, capsular, 1-celled, 3-valved, with loculicidal dehiscence. *Seeds* numerous, without albumen.

Distribution and Numbers.—Natives of the East Indies and Arabia. There is only one genus (*Moringa*, Burm.) and 4 species.

Properties and Uses.—Pungent and slightly aromatic properties more or less prevail in plants of the order; hence they have been employed as stimulants.

Artificial Analysis of the Orders in the Sub-class Polypetalæ.

Series 2. DISCIFLORÆ.

1. FLOWERS with more than 20 stamens.

Carpels more or less distinct (at least as to the styles), or solitary, superior or partially inferior. Stamens perigynous . . . *Anacardiaceæ.*
Carpels wholly combined (at least as to the ovaries), superior. Stamens hypogynous . *Humiriaceæ.*

2. FLOWERS with less than 20 stamens.

A. *Leaves generally without stipules.*
- a. *Carpels more or less distinct, or solitary.*
  - Leaves without dots.
    - Albumen abundant . . . . . *Zygophyllaceæ.*
    - Albumen absent . . . . . . *Anacardiaceæ.*
  - Leaves dotted . . . . *Burseraceæ.*
- b. *Carpels wholly combined* (*at least as to their ovaries*).
  - Styles distinct to the base.
    - Calyx valvate . . . . . . *Vivianiaceæ.*
    - Calyx imbricate . . . . . . *Linaceæ.*
  - Styles more or less combined.
    - Calyx valvate or united, or but very slightly imbricate.
      - Stamens hypogynous.
        - Calyx generally enlarging with the fruit *Olacaceæ.*
        - Calyx not enlarging with the fruit.
          - Stamens opposite to the petals, isomerous . . . . . . *Rhamnaceæ.*
          - Stamens alternate with the petals, isomerous.
            - Leaves compound . . . . *Burseraceæ.*
            - Leaves simple . . . . *Icacinaceæ.*

Stamens more or less perigynous.
Flowers irregular, ovules suspended . *Tropæolaceæ.*
Flowers regular, ovules erect . *Limnanthaceæ.*
Calyx imbricate.
Style gynobasic.
Stamens arising from scales . . *Simarubaceæ.*
Stamens not arising from scales.
Styles wholly combined.
Flowers perfect . . . . . *Rutaceæ.*
Flowers polygamous . . { *Xanthoxyleæ of Rutaceæ.*
Styles divided at the apex.
Flowers irregular, fruit usually with elastic valves . . . . *Balsaminaceæ.*
Style not gynobasic.
Calyx much imbricate, in an irregular broken whorl.
Petals with appendages at their base.
Leaves alternate . . . . *Sapindaceæ.*
Petals without appendages at their base. Leaves opposite . . *Aceraceæ.*
Calyx but little imbricate, in a complete whorl.
Carpels 4 or more.
Seeds winged . . . . . *Cedrelaceæ.*
Seeds wingless.
Stamens united into a long tube . *Meliaceæ.*
Stamens distinct, or nearly so.
Leaves dotted.
Seeds amygdaloid . . { *Aurantieæ of Rutaceæ.*
Leaves without dots.
Seeds erect . . . . *Celastraceæ.*
Carpels less than 4.
Petals imbricate.
Ovules suspended . . . *Cyrillaceæ.*
Ovules erect . . . . *Celastraceæ.*

B. *Leaves generally with stipules.*

a. *Carpels distinct, or solitary.*
Carpels several . . . . *Coriariaceæ.*
b. *Carpels wholly combined (at least as to their ovaries), with more placentas than one.*
Placentas parietal . . . . . . *Moringaceæ.*
Placentas in the axis.
Styles distinct to the base.
Petals conspicuous, stalked . . . *Malpighiaceæ.*
Styles more or less combined, gynobasic.
Gynobase fleshy . . . . . . *Ochnaceæ.*

Gynobase dry.	
Leaves regularly opposite	*Zygophyllaceæ.*
Leaves more or less alternate.	
Fruit beaked	*Geraniaceæ.*
Fruit not beaked	*Oxalidaceæ.*
Styles more or less combined, not gynobasic.	
Calyx much imbricate, in an irregular broken whorl.	
Flowers not surrounded by an involucre	*Sapindaceæ.*
Calyx but little imbricate, in a complete whorl.	
Stamens 3, sepals and petals pentamerous	*Hippocrateaceæ.*
Stamens more than 3.	
Calyx glandular.	
Petals without appendages . .	*Malpighiaceæ.*
Calyx not glandular.	
Leaves simple.	
Petals united by their claws into a tube	*Stackhousiaceæ.*
Leaves compound.	
Petals distinct	*Staphyleaceæ.*
Calyx valvate.	
Stamens opposite to the petals, isomerous.	
Seeds one in each cell	*Rhamnaceæ.*
Stamens opposite to the petals if isomerous, anthers versatile, seeds two in each cell	*Vitaceæ.*
Stamens twice as many as the petals .	*Burseraceæ.*

The following exceptions may be noted to the characters usually distinctive of the Disciforæ. We have apetalous species in *Zygophyllaceæ*, *Geraniaceæ*, *Balsaminaceæ*, *Rutaceæ*, *Simarubaceæ*, *Burseraceæ*, *Olacaceæ*, *Celastraceæ*, *Rhamnaceæ*, *Sapindaceæ*, *Anacardiaceæ*, and some others.

Gamopetalous corollas are sometimes found in *Humiriaceæ*, *Rutaceæ*, *Balsaminaceæ*, *Meliaceæ*, and *Stackhousiaceæ*.

In *Geraniaceæ*, *Balsaminaceæ*, *Tropæolaceæ*, *Oxalidaceæ*, *Aceraceæ*, *Anacardiaceæ*, *Malpighiaceæ*, *Linaceæ*, &c., the disc is small, or entirely or partially absent. The ovary is more or less inferior in some *Olacaceæ* and *Rhamnaceæ*; and the placentation is parietal instead of axile in some *Ochnaceæ* and *Moringaceæ*.

Synopsis of the British Natural Orders of the Series Disciflorœ.

A. Corolla completely polypetalous, inferior.
  Calyx imbricate in the bud.
    Corolla irregular . . . . *Balsaminaceæ.*
    Corolla regular.
      Stamens in an hypogynous ring.
        Stamens 4—5. Stipules absent . . *Linaceæ.*
        Stamens 10. Ovary 5-celled, many-seeded *Oxalidaceæ.*
        Stamens 10. Leaves stipulate. Ovary 5-celled, with one seed in each cell . *Geraniaceæ.*
      Stamens free.
        Style solitary. Stamens and petals 4—5, inserted on an hypogynous disc . . *Celastraceæ.*
  Calyx valvate in the bud.
    Stamens perigynous, opposite to the petals . *Rhamnaceæ.*
B. Corolla gamopetalous, or with petals connate at the base.
  Fruit fleshy . . . . *Aquifoliaceæ.*

Series 3.—*Calycifloræ.*

Cohort 1.—*Rosales.*

Order 119. CONNARACEÆ, the Connarus Order.—Character. *Trees* or *shrubs. Leaves* alternate, without dots, compound, and generally exstipulate. *Flowers* usually perfect, or rarely unisexual. *Calyx* 5-partite, inferior, imbricate or valvate in æstivation. *Petals* 5, inserted on the calyx, imbricate or valvate. *Stamens* 10, usually monadelphous, nearly or quite hypogynous. *Carpels* 1 or more; *ovules* 2, sessile, collateral, ascending, orthotropous. *Fruit* follicular. *Seeds* with or without albumen, arillate or exarillate; *radicle* superior, at the extremity most remote from the hilum.

Distribution and Numbers.—Natives of the tropics, and most common in tropical America. *Illustrative Genera:*—Connarus, Omphalobium. There are about 42 species.

Properties and Uses.—Some have oily seeds; others, as certain species of *Omphalobium*, have edible arils. The zebra-wood of the cabinetmakers is said by Schomburgk to be furnished by *Omphalobium Lamberti*, a very large Guiana tree.

Order 120. LEGUMINOSÆ, the Pea and Bean Order.—Character.—*Herbs, shrubs,* or *trees. Leaves* alternate, stipulate, usually compound. *Calyx* gamosepalous, inferior, more or less deeply divided into five parts, the odd division being anterior. *Petals* usually five, or sometimes by abortion 4, 3, 2, 1, or rarely

none, inserted into the base of the calyx ; equal or unequal ; often papilionaceous, the odd petal, if any, posterior. *Stamens* definite or indefinite, usually perigynous, or rarely hypogynous, distinct or united into 1, 2, or rarely 3 bundles. If in two bundles these contain respectively 9 and 1. *Ovary* superior, usually formed of 1 carpel, although rarely of 2 or 5 ; 1-celled with 1, 2, or many ovules ; *style* and *stigma* simple. *Fruit* usually a legume, or sometimes a lomentum, or rarely a drupe. *Seeds* 1 or more, sometimes arillate, attached to the upper or ventral suture ; *albumen* usually absent ; *embryo* straight, or with the radicle folded upon the cotyledons ; *cotyledons* leafy or fleshy, and either hypogeal or epigeal.

Diagnosis.—Herbs, shrubs, or trees. Leaves nearly always alternate and stipulate, and usually compound. Flowers regular or irregular. Calyx inferior, 5-partite ; odd division anterior. Petals 5, and then unequal or equal ; or fewer by abortion, or

FIG. 1092.

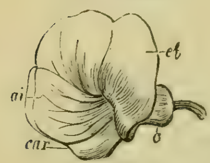


FIG. 1093.

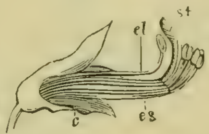


FIG. 1094.

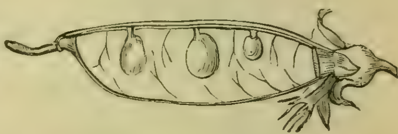


Fig. 1092. The flower of the Pea (*Pisum*). *el.* Standard or vexillum. *ai.* Wings or alæ. *car.* Carina or keel enclosing the sporophylls. *c.* Calyx.——*Fig.* 1093. The sporophylls of the same surrounded by the calyx *c.* *es.* Bundle of nine stamens. *el.* Solitary stamen. *st.* Style and stigma.——*Fig.* 1094. Legume of the same, with one valve removed.

none ; perigynous ; odd one, when present, posterior. Stamens distinct, or united into one or more bundles. Ovary superior, simple, 1-celled ; style simple, proceeding from the ventral suture. Fruit usually a legume, sometimes a lomentum, or rarely a drupe. Seeds 1 or more, usually without albumen. *This order may be generally distinguished by having leguminous fruit.*

Division of the Order and Illustrative Genera.—The order has been divided into three sub-orders as follows :—

Sub-order 1. PAPILIONACEÆ.—Petals arranged so as to form a papilionaceous corolla, imbricate in æstivation, and the upper or odd petal exterior to the lateral petals. *Illustrative Genera :*—Ulex, *Linn.* ; Trifolium, *Linn.* ; Vicia, *Linn.* ; Ornithopus, *Linn.*

Sub-order 2. CÆSALPINIEÆ.—Petals not arranged in a papilionaceous manner, imbricate in æstivation, and the upper

or odd petal with its margins inside the lateral petals. *Illustrative Genera:*—Cæsalpinia, *Linn.*; Cassia, *Linn.* There are no British plants in this sub-order.

Sub-order 3. MIMOSEÆ.—Petals equal, valvate in æstivation. Stamens often ∞. Pollen slightly coherent. Leaves sometimes replaced by phyllodes. *Illustrative Genera:*—Mimosa, *Linn.*; Acacia, *Willd.* There are no British plants in this sub-order.

Distribution and Numbers.—This is a very extensive order, and has some representatives in almost every part of the world. A considerable number of the genera are, however, confined within certain geographical limits, while others have a very wide range. As a general rule, the *Papilionaceæ* are universally distributed, although most abundant in warm regions; while the *Cæsalpinieæ* and *Mimoseæ* are most common in the tropics; but many of the latter are also to be found in Australia. There are about 7,000 species in this order.

Properties and Uses.—The properties and uses of the plants of this order are exceedingly variable. Many are valuable fodder plants, others yield timber, gums, drugs, and dyes. Some species are poisonous.

Order 121. ROSACEÆ, the Rose Order.—Character.—*Trees, shrubs*, or *herbs*. *Leaves* simple or compound, alternate, usually stipulate. *Flowers* regular, generally hermaphrodite, or rarely unisexual. *Thalamus* more or less convex, elongated, or concave, or tubular; the tube sometimes becoming fleshy as the fruit develops, and often so enclosing the carpels as to make the fruit spuriously syncarpous and inferior. *Calyx* gamosepalous, sometimes partly adherent to the tube of the thalamus; 4- or 5-lobed; when 5, the odd lobe posterior; sometimes surrounded by a whorl of bracts forming an *involucre* or *epicalyx*. These are by some botanists considered to represent stipules of the sepals. *Petals* 5, distinct, perigynous; or rarely none. *Stamens* definite or ∞, perigynous. *Carpels* 1, 2, 5, or numerous, with 1-celled ovaries; usually apocarpous and superior; sometimes becoming spuriously syncarpous and inferior during the development of the fruit, as in the *Pomeæ; styles* basilar, lateral, or terminal; *ovules* 1 or few. *Fruit* various: either a drupe, an achænium, a follicle, a dry or succulent etærio, a cynarrhodon, or a pome. *Seeds* 1 or few, exalbuminous; *embryo* straight.

Diagnosis.—Trees, shrubs, or herbs, with alternate leaves. Flowers regular. Calyx 4—5-lobed; when 5, the odd lobe pos-

terior. Petals 5, perigynous, or rarely none. Stamens perigynous, distinct; anthers 2-celled. Carpels one or more, usually distinct or sometimes ultimately united; generally superior or occasionally becoming more or less inferior during development of the fruit. Seeds 1 or few, exalbuminous; embryo straight.

Division of the Order and Illustrative Genera.—The order Rosaceæ, as above defined, may be divided into five sub-orders, which are by some botanists considered as distinct orders. They are characterised as follows:—

Sub-order 1. CHRYSOBALANEÆ.—Trees or shrubs, with simple leaves and free stipules. Carpel solitary, cohering more or less on one side with the tube of the thalamus; ovules 2; style basilar. Fruit a drupe. Seed erect; radicle inferior. *Illustrative Genus:*—Chrysobalanus, *Linn.* There are no British plants in this sub-order.

FIG. 1095.

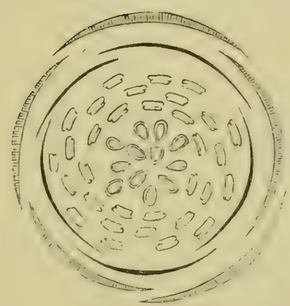


FIG. 1096.

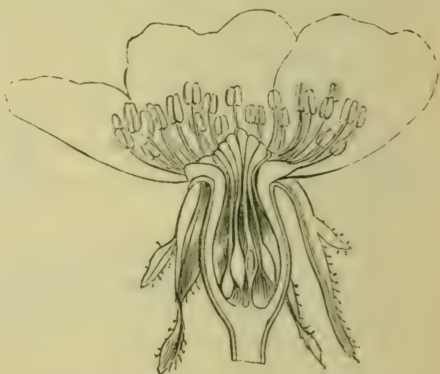


Fig. 1095. Diagram of the flower of a species of Rose, with five sepals, five petals, numerous stamens, and many distinct carpels.——*Fig.* 1096. Vertical section of the flower.

Sub-order 2. DRUPACEÆ.—Trees or shrubs, with simple leaves and free stipules. Calyx deciduous. Carpel solitary, free; style terminal. Fruit a drupe. Seed suspended. *Illustrative Genus:*—Prunus, *Linn.*

Sub-order 3. ROSEÆ.—Shrubs or herbs, with simple or compound leaves and adherent stipules. Carpels 1 or more, superior, not united to the tube of the thalamus, distinct or sometimes more or less coherent; styles lateral or nearly terminal. Fruit either an etærio, a cynarrhodon, or several follicles. Seed usually suspended, or rarely ascending; radicle superior. *Illustrative Genera:*—Rosa, *Linn.*; Rubus, *Linn.*

Sub-order 4. SANGUISORBEÆ or POTERIEÆ.—Herbs or undershrubs. Flowers often unisexual. Petals frequently absent. Carpels 1—3; style terminal or basilar. Fruit an achænium enclosed in the tube of the thalamus, which is often indurated.

FIG. 1097.

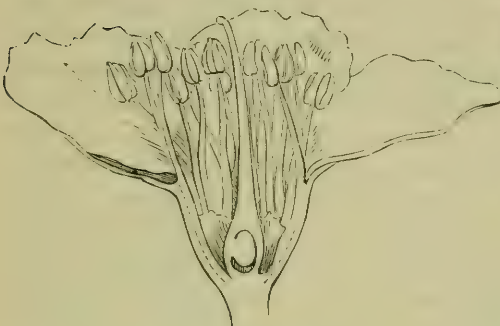
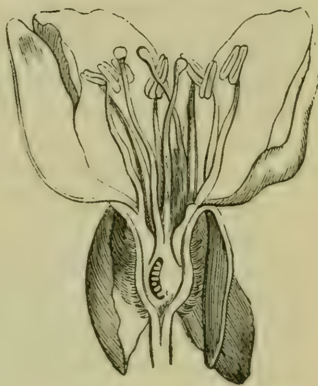


FIG. 1098.



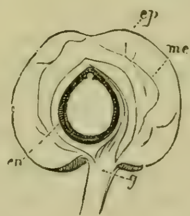


FIG. 1099. FIG. 1100. FIG. 1101. FIG. 1102. FIG. 1103.

Fig. 1097. Vertical section of the flower of the Peach (*Prunus* (*Amygdalus*) *persica*).——*Fig.* 1098. Vertical section of the flower of the Quince (*Pyrus Cydonia*).——*Fig.* 1099. Two-celled anther with part of the filament of a species of *Rubus*.——*Fig.* 1100. Vertical section of the flower of a species of *Alchemilla*.——*Fig.* 1101. Vertical section of the fruit (*drupe*) of the Cherry (*Prunus Cerasus*). *ep.* Epicarp. *me.* Mesocarp. *en.* Endocarp, within which is the seed with embryo.——*Fig.* 1102. Vertical section of an achænium of a species of Rose.——*Fig.* 1103. Vertical section of the ovary, *o*, of a species of *Rubus*, with the ovule, *ov*.

Seed solitary, suspended, erect, or ascending. *Illustrative Genera*:—Alchemilla, *Linn.*; Poterium, *Linn.*

Sub-order 5. POMEÆ.—Trees or shrubs, with simple or compound leaves and free stipules. Carpels 1 to 5, cohering more or less with each other and united to the sides of the tube of the thalamus, thus becoming inferior; styles terminal. Fruit

a pome, 1—5-celled or rarely spuriously 10-celled. Seeds erect or ascending. *Illustrative Genera:*—Pyrus, *Linn.*; Cratægus, *Linn.*

Distribution and Numbers.—The *Chrysobalaneæ* are principally natives of the tropical parts of America and Africa. The *Drupaceæ* are almost exclusively found in the cold and temperate regions of the northern hemisphere. The *Roseæ* and *Sanguisorbeæ* are also chiefly natives of cold and temperate climates, although a few are found within the tropics. The *Pomeæ* occur only in the cold and temperate regions of the northern hemisphere. The order Rosaceæ comprises about 1,000 species, of which about one-half belong to the sub-order Roseæ.

Properties and Uses.—The plants of the order are principally remarkable for their astringency, and for their succulent edible fruits. The seeds, flowers, leaves, and young shoots of many of the *Drupaceæ* and *Pomeæ*, when moistened with water, yield hydrocyanic acid; hence parts of such plants are sometimes poisonous. All other Rosaceæ are entirely devoid of poisonous properties.

Order 122. SAXIFRAGACEÆ, the Saxifrage Order.—Character.—*Herbs* with alternate *leaves*, which are entire or lobed, stipulate or exstipulate. *Calyx* of 4 or 5 sepals, which are more or less united at the base, inferior or more or less superior. *Petals* 4 or 5, perigynous, imbricate, alternate with the lobes of the calyx, sometimes wanting. *Stamens* 5—10, perigynous or epigynous; *anthers* 2-celled, with longitudinal dehiscence. *Disc* usually evident, either existing in the form of 5 scaly processes, or annular and notched, epigynous or perigynous. *Ovary* superior or more or less inferior, usually composed of two carpels, united below, but more or less distinct towards the apex; 1- or 2-celled; *styles* equal in number to the carpels, distinct, diverging. *Fruit* capsular, 1—2-celled, usually membranous. *Seeds* small, numerous; *embryo* in the axis of fleshy albumen, and with the radicle towards the hilum.

Diagnosis.—Herbs with alternate leaves. Calyx inferior or generally more or less superior, 4—5-partite. Stamens perigynous or epigynous. Ovary superior or more or less inferior, composed of 2 carpels united at the base, and diverging at the apex; styles distinct, equal in number to the carpels. Fruit capsular, 1—2-celled. Seeds numerous, small, with fleshy albumen.

Bentham and Hooker include the succeeding orders, Francoaceæ, Escalloniaceæ, Philadelphaceæ, Hydrangeaceæ, Hen-

sloviaceæ, Cunoniaceæ, and Ribesiaceæ, in the order Saxifragaceæ, and arrange the whole in the following sub-orders:—1. *Saxifrageæ.* 2. *Francoeæ.* 3. *Escallonieæ.* 4. *Philadelpheæ* or *Hydrangeæ.* 5. *Cunonieæ.* 6. *Ribesieæ.*

Distribution and Numbers.—They are exclusively natives of the northern parts of the world, where they chiefly inhabit mountainous districts, and sometimes grow as high as 16,000 feet above the level of the sea. *Illustrative Genera*:—Saxifraga, *Linn.*; Heuchera, *Linn.* There are about 320 species.

FIG. 1104.

FIG. 1105.

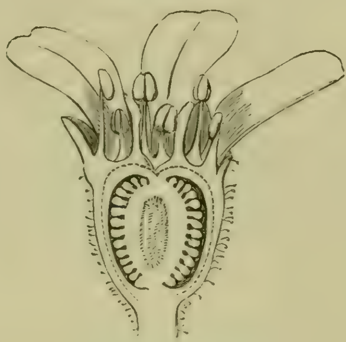


FIG. 1106.

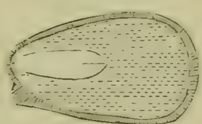


Fig. 1104. *Saxifraga tridactylites.* The leaves are trifid and wedge-shaped, and the flowers arranged in a cyme.——*Fig.* 1105. Vertical section of the flower.——*Fig.* 1106. Vertical section of the seed.

Properties and Uses.—The plants of the order are all more or less astringent. This is remarkably the case with the root of *Heuchera americana*, which is much employed for its astringent properties in the United States under the name of *Alum-root.*

Order 123. FRANCOACEÆ, the Francoa Order.—Character. Stemless *herbs. Leaves* exstipulate. *Calyx* 4-partite. *Petals* 4, persistent. *Stamens* hypogynous or nearly so, four times as many as the petals, the alternate ones sterile, and commonly termed scales. *Ovary* superior, 4-celled; *ovules* numerous;

stigma sessile, 4-lobed. *Fruit* a membranous 4-celled, 4-valved capsule, with loculicidal or septicidal dehiscence. *Seeds* small, indefinite ; *embryo* very minute, at the base of a large quantity of fleshy albumen.

Distribution and Numbers.—Natives of Chili. *Illustrative Genera :*—Francoa, *Cavan.*; Tetilla, *DC.* These are the only genera ; they include about 6 species.

Properties and Uses.—The *Francoas* are reputed to be cooling and sedative. *Tetilla* is astringent, and is employed as a remedy in dysentery.

Order 124. ESCALLONIACEÆ, the Escallonia Order.—Character.—Evergreen *shrubs*, with alternate exstipulate glandular leaves and axillary showy flowers. *Calyx* superior, 5-toothed, imbricate in æstivation. *Petals* 5, alternate with the divisions of the calyx, perigynous, or rarely hypogynous. *Stamens* 5, alternate with the petals, perigynous, or rarely hypogynous. *Ovary* inferior, 2—5-celled, crowned by a cone-shaped disc ; *placentas* axile ; *style* simple ; *stigmas* 2—5-lobed. *Fruit* capsular or baccate, crowned by the persistent style and calyx. *Seeds* very numerous, minute ; *embryo* small, in a mass of oily albumen.

Distribution and Numbers.—They are chiefly natives of the mountains of South America. *Illustrative Genera :*—Escallonia, *Mutis* ; Itea, *Linn.* ; Brexia, *Thouars.* There are more than 66 species.

Properties and Uses.—Unknown.

Brexia.—This genus has been made the type of a distinct order, named Brexiaceæ ; but Bentham and Hooker place it near the genus *Escallonia.*

Order 125. PHILADELPHACEÆ, the Syringa Order.—Character.—*Shrubs.* *Leaves* opposite, simple, deciduous, exstipulate. *Calyx* superior, persistent, 4—10-lobed, with a valvate æstivation. *Petals* equal in number to the divisions of the calyx, and alternate with them. *Stamens* numerous, epigynous. *Ovary* inferior ; *styles* united or distinct ; *stigmas* several. *Capsule* half-inferior, 4—10-celled, *placentas* axile. *Seeds* numerous, with fleshy albumen.

Distribution and Numbers.—Natives of the South of Europe, North America, Japan, and India. *Illustrative Genera :*—Philadelphus, *Linn.* ; Deutzia, *Thunb.* There are about 25 species.

Properties and Uses.—Of little importance.

Order 126. HYDRANGEACEÆ, the Hydrangea Order.—*Dia-*

gnosis.—This order is frequently regarded as a sub-order of Saxifragaceæ, with which it agrees in many important particulars; but it differs in its plants being of a shrubby nature; in their having opposite leaves, which are always exstipulate; in their valvate calyx; in their tendency to a polygamous structure, as exhibited in the possession of radiant staminal flowers; and in having frequently more than 2 carpels, with a corresponding increase in the number of styles and cells to the ovary.

Distribution and Numbers.—Natives chiefly of the temperate regions of Asia and America. About one-half of the species are natives of China and Japan. *Illustrative Genera:*—Hydrangea, *DC.*; Bauera, *Sm.* There are about 45 species.

Properties and Uses.—Unimportant.

Order 127. HENSLOVIACEÆ, the Henslovia Order.—*Diagnosis.*—This is a small order of tropical plants, containing but 1 genus and 3 or 4 species, which was considered by Lindley to be nearly allied to Hydrangeaceæ; but distinguished by their tree-like habit, their styles being united into a cylinder, and the total absence of albumen. *Illustrative Genus:*—Henslovia, *Wall.*

Properties and Uses.—Unknown.

Order 128. CUNONIACEÆ, the Cunonia Order.—*Diagnosis.*—Nearly allied to Saxifragaceæ, but differing from them in being trees or shrubs, with opposite or whorled leaves, and large interpetiolar stipules. The latter character will also distinguish them readily from Hydrangeaceæ, which are exstipulate. They are also known from the latter order by their calyx not being valvate.

Distribution and Numbers.—Natives of South America, the Cape, the East Indies, and Australia. *Illustrative Genera:*—Weinmannia, *Linn.*; Cunonia, *Linn.* There are about 100 species.

Properties and Uses.—Astringent. Some have been used for tanning; others exude a gummy secretion.

Order 129. RIBESIACEÆ, the Currant Order.—Character.—*Shrubs* with or without spines or prickles. *Leaves* alternate, simple, lobed, radiate-veined. *Inflorescence* axillary, racemose. *Flowers* perfect or rarely unisexual. *Calyx* superior, 4—5-lobed. *Petals* 4—5, minute, inserted on the calyx. *Stamens* 4—5, perigynous, alternate with the petals. *Ovary* inferior, 1-celled, with 2 parietal placentas. *Fruit* a berry. *Seeds* numerous; *embryo* minute, in horny albumen.

Distribution and Numbers.—Natives of the temperate regions

of Europe, Asia, and North America. *Illustrative Genera:*—Ribes, *Linn.*; Polyosma, *Br.* These are the only genera; they include about 100 species.

Properties and Uses.—Some are showy garden plants, as *Ribes fuchsioides*, *R. sanguineum*, *R. aureum*, *R. coccineum*; but they are chiefly remarkable for their agreeable acid fruits. Thus the fruit of *Ribes Grossularia* is the Gooseberry; *R. rubrum* and its varieties yield both Red and White Currants; and *R. nigrum* is the Black Currant.

Order 130. CRASSULACEÆ, the Houseleek Order.—Character.—*Succulent herbs* or *shrubs*. *Leaves* entire or pinnatifid, exstipulate. *Flowers* symmetrical. *Calyx* generally composed of 5 sepals, but varying in number from 3 to 20, more or less united at the base, inferior, persistent. *Petals* equal in number to the divisions of the calyx, with which they are alternate; either distinct or united, and inserted into the bottom of the calyx; *æstivation* imbricate. *Stamens* inserted with the petals, either equal to them in number and alternate with them; or twice as many, and then forming 2 whorls, one of which is composed of longer stamens than the other, the longer stamens being placed alternate to the petals, and the shorter stamens opposite to them; *anthers* adnate, 2-celled, with longitudinal dehiscence. *Carpels* equal in number to the petals and opposite to them, each having frequently a scale on the outside at the base; distinct or more or less united; *styles* distinct. *Fruit* either consisting of a whorl of follicles, or a capsule with loculicidal dehiscence. *Seeds* very small, variable in number; *embryo* in the axis of fleshy albumen, with the radicle towards the hilum.

Diagnosis.—Succulent herbs or low shrubs. Leaves exstipulate. Flowers perfectly symmetrical, the sepals, petals, and carpels being equal in number and the stamens being also equal to them, or twice as many. Petals and stamens almost hypogynous. Corolla gamopetalous or polypetalous. Carpels opposite the petals. Fruit either apocarpous and follicular, or a many-celled capsule with loculicidal dehiscence. Seeds small; embryo in the axis of fleshy albumen.

Division of the Order and Illustrative Genera:—The order may be divided as follows:—

Sub-order 1. CRASSULEÆ.—Fruit consisting of a whorl of follicles. Crassula, *Haw.*; Sedum, *Linn.*

Sub-order 2. DIAMORPHEÆ.—Fruit a many-celled capsule with loculicidal dehiscence. Diamorpha, *Nutt.*; Penthorum, *Linn.*

Distribution and Numbers.—They are found in very dry situations in all parts of the world; a large number occur at the Cape of Good Hope. There are about 450 species.

Properties and Uses.—Astringent, refrigerant, and acrid properties are found in the plants of this order, but none are of much importance.

Order 131. DROSERACEÆ, the Sundew Order.—Character. Herbaceous plants growing in boggy or marshy places, frequently glandular. *Leaves* alternate, fringed at their margins and with a circinate vernation. *Inflorescence* helicoid. *Sepals* and *petals* 5, hypogynous, equal, imbricate, persistent. *Stamens* as many as the petals and alternate with them, or twice, thrice, or four times as many, distinct, withering, hypogynous; *anthers* innate or versatile, extrorse. *Ovary* superior, 1-celled, with parietal placentation; *styles* 3—5, distinct or connected at the base; *ovules* numerous, anatropous. *Fruit* capsular, 1-celled, bursting by 3 or 5 valves, which bear the placentas in their middle or at their base; hence the dehiscence is loculicidal. *Seeds* numerous, with or without an aril; *embryo* minute at the base of abundant fleshy albumen.

Diagnosis.—Bog or marsh herbs, with alternate exstipulate leaves and a circinate vernation. Inflorescence helicoid. Flowers regular and symmetrical, hypogynous, with a quinary arrangement of their parts, which are also persistent and imbricate. Anthers extrorse. Placentas parietal. Fruit capsular, 1-celled, with loculicidal dehiscence. Seeds numerous; embryo small, at the base of copious fleshy albumen.

Distribution and Numbers.—These plants are found in almost all parts of the world with the exception of the Arctic regions. *Illustrative Genera*:—Drosera, *Linn.*; Dionæa, *Ellis.* There are about 110 species in this order.

Properties and Uses.—They possess slightly acid and acrid properties. The plants of the order are chiefly interesting from the peculiar irritability of the glands on their leaves. Thus, the leaves of the Droseras are fringed with stalked glands, which curve over and imprison any insects that alight upon the leaf-blade; while the plant known as Venus's Flytrap (*Dionæa muscipula*), a native of North America, has two-lobed leaves, each lobe furnished on its upper surface with three stiff hairs; these, when touched, cause the two lobes of the leaf to shut together face to face and enclose the object touching them. The glands in these plants secrete a viscid acid digestive fluid,

so that insects which are imprisoned by them become ultimately dissolved and absorbed for their nourishment.

Order 132. HAMAMELIDACEÆ, the Witch-hazel Order.—Character.—Small *trees* or *shrubs*, with alternate simple *leaves* and deciduous stipules. *Flowers* in globular heads or spicate, perfect or unisexual, polygamous or monœcious. *Calyx* superior, 4- or 5-lobed. *Petals* 4 or 5, with an involute or circinate æstivation, or altogether wanting. *Stamens* 8, half of which are scale-like, sterile, and placed opposite to the petals, and half fertile and alternate with them; or numerous. *Ovary* inferior, 2-celled; *ovules* solitary or numerous; *styles* 2. *Fruit* capsular, 2-celled, with 1 seed in each cell; *seeds* albuminous.

Distribution and Numbers.—Natives of North America, Asia, and Africa. *Illustrative Genera:*—Hamamelis, *Linn.*; Liquidambar, *Linn.* There are about 25 species.

Properties and Uses.—Chiefly remarkable for their fragrant balsamic properties. Some have acrid bitter barks; and the leaves and bark of others are astringent.

Order 133. BRUNIACEÆ, the Brunia Order.—Character.—Heath-like *shrubs*, with small imbricate, rigid, entire, exstipulate *leaves*. *Calyx* usually superior, or sometimes nearly inferior, imbricate. *Petals* and *stamens* 5, inserted on the calyx, the petals alternate with the divisions of the calyx and valvate; *anthers* 2-celled, extrorse, bursting longitudinally. *Ovary* superior or half inferior, 1–3-celled, with 1 or 2 suspended anatropous ovules in each cell; *style* simple or bifid. *Fruit* crowned by the remains of the calyx and a disc; 1—2-celled, in the first case indehiscent, in the latter dehiscent. *Seeds* with a minute embryo, in fleshy albumen.

Distribution and Numbers.—Natives of the Cape of Good Hope, except one Madagascar species. *Illustrative Genera:*—Brunia, *Linn.*; Ophiria, *Linn.* There are about 60 species.

Properties and Uses.—Unknown.

Order 134. HALORAGACEÆ, the Mare's-tail order.—*Diagnosis.* *Herbs* or *shrubs*, generally aquatic. *Flowers* small, frequently incomplete and unisexual. They are nearly allied to Onagraceæ, and, in fact, have been considered a degenerate form of that order. They are distinguished from it by their minute calyx, the limb of which is frequently obsolete; and by having solitary pendulous seeds, with fleshy albumen.

Distribution and Numbers.—They are found in all parts of the world. *Illustrative Genera:*—Hippuris, *Linn.*; Trapa, *Linn.* There are about 70 species.

Properties and Uses.—Of little importance except for their edible seeds.

Order 135. CALLITRICHACEÆ, the Starwort Order.—Character.—Small aquatic *herbs*. *Leaves* simple, opposite, entire. *Flowers* minute, axillary, solitary, unisexual, achlamydeous. *Male flower* of 1—2 *stamens*; *anthers* reniform. *Female flower* with a 4-cornered, 4-celled *ovary*, with 1 pendulous ovule in each cell. *Fruit* indehiscent, 4-celled. *Seeds* 4, pendulous, with fleshy albumen; *embryo* inverted, with a very long superior radicle.

Distribution.—Natives of freshwater pools in Europe and North America. *Callitriche* is the only genus; it includes several species or varieties.

Properties and Uses.—Unknown.

Cohort 2.—*Myrtales.*

Order 136. RHIZOPHORACEÆ, the Mangrove Order.—Character.—*Trees* or *shrubs*. *Leaves* simple, opposite, dotless or rarely dotted, with deciduous interpetiolar stipules. *Calyx* superior, 4—12-lobed, with a valvate æstivation, the lobes sometimes united so as to form a calyptra. *Petals* arising from the calyx, alternate with its lobes and equal to them in number. *Stamens* on the calyx, twice or thrice as many as its lobes, or still more numerous. *Ovary* inferior, 2- 3- or 4-celled, each cell with 2 or more ovules. *Fruit* indehiscent, 1-celled, 1-seeded, crowned by the calyx. *Seeds* pendulous, exalbuminous, usually germinating while the fruit is still attached to the tree.

Distribution and Numbers.—Natives of muddy seashores in tropical regions. *Illustrative Genera*:—Rhizophora, *Lam.*; Bruguiera, *Lam.* There are about 20 species.

Properties and Uses.—Generally remarkable for their astringent properties, whence they are used for dyeing and tanning; they are also used medicinally for their febrifugal and tonic properties.

Order 137. COMBRETACEÆ, the Myrobalans Order.—Character.—*Trees* or *shrubs*. *Leaves* alternate or opposite, exstipulate, entire, without dots, *Flowers* perfect or unisexual. *Calyx* superior, with a 4—5-lobed deciduous limb. *Petals* equal in number to, and alternate with, the lobes of the calyx; often absent. *Stamens* inserted with the petals on the calyx, generally twice as numerous as its lobes, or thrice as many, or sometimes equal to them in number; *anthers* 2-celled, with longitudinal or valvular dehiscence. *Ovary* inferior, 1-celled,

with 2—4 ovules; *style* and *stigma* simple. *Fruit* indehiscent, 1-seeded. *Seeds* pendulous, exalbuminous; *cotyledons* leafy, convolute or plaited.

Distribution and Numbers.—Exclusively natives of the tropical parts of America, Africa, and Asia. *Illustrative Genera:* Terminalia, *Linn.*; Combretum, *Löffl.* There are about 200 species.

Properties and Uses.—The order is chiefly remarkable for the presence of an astringent principle; hence the bark of some species, and the fruits and flowers of others, are employed in tanning and dyeing. Some yield excellent timber.

Fig. 1107.

Fig. 1107. Flowering branch of the common Myrtle (*Myrtus communis*).

Order 138. MYRTACEÆ, the Myrtle Order.—Character.—*Trees* or *shrubs.* *Leaves* opposite or alternate, entire, exstipulate, usually dotted, and having a vein running just within their margins. *Calyx* superior, 4- or 5-cleft, valvate, sometimes separating in the form of a cap. *Petals* 4—5, imbricate, rarely absent. *Stamens* usually 8—10, or numerous, or rarely 4—5; *filaments* distinct or polyadelphous. *Ovary* inferior, 1—6-celled; *style* and *stigma* simple; *placentas* axile, or very rarely parietal. *Fruit* dry or succulent, dehiscent or indehiscent. *Seeds* without albumen, usually numerous.

Division of the Order and Illustrative Genera.—The order may be divided into two tribes as follows:—

Tribe 1. *Leptospermæ.*—Fruit capsular. *Illustrative Genera:* Melaleuca, Leptospermum.

Tribe 2. *Myrteæ.*—Fruit baccate. *Illustrative Genera:*—Punica, *Linn.*; Myrtus, *Tourn.*

Distribution and Numbers.—Natives of the tropics and of the warmer parts of the temperate zones. *Myrtus communis*, the common Myrtle, is the most northern species of the order. This plant, although now naturalised in the South of Europe,

was originally a native of Persia. There are about 1,320 species belonging to this order.

Properties and Uses.—These plants are generally remarkable for aromatic and pungent properties, which are due to the presence of volatile oils. Many of these oils have been used in medicine as stimulants, aromatics, carminatives, diaphoretics, or antispasmodics; and also in perfumery. The dried flower-buds and unripe fruits of some species are in common use as spices. Other plants of the order are astringent, and a few secrete a saccharine matter. The fruits of some having a sweetish acidulous taste are edible. Many are valuable timber-trees.

Order 139. LECYTHIDACEÆ, the Brazil-nut Order.—Character.—Large *trees*, with alternate dotless *leaves*, and small deciduous *stipules*. *Flowers* large and showy. *Calyx* superior. *Petals* 6, imbricate, distinct, or sometimes united at the base. *Stamens* numerous, epigynous; some of them cohering so as to form a unilateral petaloid hooded body. *Ovary* inferior, 2—6-celled; *placentas* axile. *Fruit* woody, either indehiscent or opening in a circumscissile manner. *Seeds* several, large, and without albumen. *This order is referred to Myrtaceæ by Bentham and Hooker.*

Distribution and Numbers.—Principally natives of Guiana and Brazil, and also occasionally of other hot regions of South America. *Illustrative Genera*:—Lecythis, *Löffl.*; Bertholletia, *Humb. et Bonpl.* There are about 40 species.

Properties and Uses.—These plants are chiefly remarkable for their large woody fruits, the pericarps of which are used as drinking-vessels and for other purposes. Their seeds are frequently edible.

Order 140. BARRINGTONIACEÆ, the Barringtonia Order.—*Diagnosis.*—This is a small order of plants frequently placed among the Myrtaceæ, but differing from that order in the presence of a large quantity of albumen in their seeds, in their having alternate dotless and often serrated leaves, and in the æstivation of the calyx, which in Myrtaceæ is valvate, while in Barringtoniaceæ it is imbricate.

Distribution and Numbers.—Natives of tropical regions in all parts of the world. *Illustrative Genera*:—Barringtonia, *Forsk.*; Gustavia, *Linn.*

Properties and Uses.—The bark of *Stravadium racemosum* is reputed to be febrifugal, and the root bitter, aperient, and acrid. The fruit of *Careya arborea* is eaten, while that of *Gustavia brasiliana* is emetic, and produces an intoxicating

effect upon fish. Generally the plants of the order should be regarded as somewhat dangerous.

Order 141. CHAMÆLAUCIACEÆ, the Fringe-myrtle Order.—*Diagnosis.*—This is a small order of shrubby plants with evergreen dotted leaves, and nearly allied to Myrtaceæ, but distinguished from them by their heath-like aspect, their more or less fringed scaly or bristly calyx-tube, and their 1-celled ovary. From Lecythidaceæ they are known by their habit, their dotted exstipulate leaves, and 1-celled ovary.

Distribution and Numbers.—Exclusively natives of Australia. *Illustrative Genera :*—Chamælaucium, *Desf.*; Darwinia, *Rudg.* There are more than 50 species.

Properties and Uses.—Unknown.

Order 142. BELVISIACEÆ, the Belvisia Order.—Character.—*Shrubs. Leaves* alternate, exstipulate, with a leathery texture. *Calyx* superior, coriaceous, 5-partite, with a valvate æstivation. *Corolla* consisting of three distinct whorls of united petals. *Stamens* 20, somewhat polyadelphous. *Disc* fleshy, and forming a cup-shaped expansion over the ovary. *Ovary* 5-celled, with two ovules in each cell; *placentas* axile; *style* 5-angled or 5-winged; *stigma* flat, pentagonal. *Fruit* a soft rounded berry crowned by the calyx. *Seeds* large, kidney-shaped, exalbuminous.

Distribution and Numbers.—Natives of tropical Africa and Brazil. *Illustrative Genera :*—Asteranthos, *Desf.*; Napoleona, *Palis.* These are the only genera; they include 4 species.

Properties and Uses.—Nothing is known of the uses of these plants, except that the pulp of their fruits is edible, and the pericarp contains much tannic acid.

Order 143. MELASTOMACEÆ, the Melastoma Order.—Character.—*Trees, shrubs,* or *herbs. Leaves* opposite, and almost always with several large curved ribs, and dotless. *Flowers* showy. *Calyx* 4- 5- or 6-lobed, more or less adherent to the ovary, imbricate. *Petals* equal in number to the divisions of the calyx, twisted in æstivation. *Stamens* equal in number to, or twice as many as, the petals; *filaments* curved downwards in æstivation; *anthers* long, 2-celled, curiously beaked, usually dehiscing by two pores at the apex, or sometimes longitudinally; in æstivation lying in spaces between the ovary and sides of the calyx. *Ovary* more or less adherent, many-celled; *placentation* axile. *Fruit* either dry, distinct from the calyx, and indehiscent; or succulent, united to the calyx, and indehiscent. *Seeds* very numerous, minute, exalbuminous.

Distribution and Numbers.—They are principally natives of tropical regions, but a few are also extra-tropical, being found in North America, China, Australia, and also in the northern provinces of India. *Illustrative Genera :*—Melastoma, *Juss.* ; Medinilla, *Gaud.* There are about 2,000 species.

Properties and Uses.—The prevailing character of these plants is a slight degree of astringency. Many produce edible fruits, and some are used for dyeing. Generally speaking, the plants of this order possess but little interest from a medicinal or economic point of view, but none are unwholesome. A number of species are cultivated in this country on account of the beauty of their flowers.

Order 144. LYTHRACEÆ, the Loosestrife Order.—Character.

FIG. 1108.

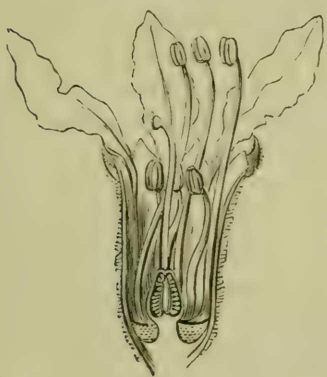


FIG. 1109.

Fig. 1108. Vertical section of the flower of the Purple Loosestrife (*Lythrum Salicaria*).—*Fig.* 1109. Calyx of the same.

Herbs or rarely *shrubs*, frequently 4-sided. *Leaves* opposite or rarely alternate, entire, and exstipulate. *Flowers* regular or irregular. *Calyx* persistent, ribbed, tubular below, the lobes with a valvate æstivation, sometimes with intermediate teeth. *Petals* inserted between the lobes of the calyx and alternate with them, occasionally wanting; deciduous. *Stamens* perigynous, inserted below the petals, to which they are equal in number, or twice as many, or even more numerous ; *anthers* adnate, 2-celled, opening longitudinally. *Ovary* superior, 1- 2- or 6-celled ; *ovules* numerous or rarely few ; *style* 1, filiform ; *stigma* capitate or rarely 2-lobed. *Fruit* capsular, membranous, dehiscent, surrounded by the non-adherent calyx-tube. *Seeds*

numerous, with or without wings, exalbuminous; *placentation* axile; *embryo* straight, with flat leafy cotyledons, and the radicle towards the hilum.

Diagnosis.—Herbs or shrubs, with entire exstipulate usually opposite leaves. Calyx tubular, ribbed, persistent, bearing the deciduous petals and stamens; the latter being inserted below the petals. Anthers 2-celled, adnate, bursting longitudinally. Ovary superior, with axile placentation; style 1. Fruit membranous, dehiscent, surrounded by the non-adherent calyx-tube. Seeds numerous, exalbuminous.

FIG. 1110.

Fig. 1110. Vertical section of the flower of a species of Willow-herb (*Epilobium*).

Distribution and Numbers.—The greater number are tropical plants, but some are also found in temperate regions, as, for instance, in Europe and North America. One species only, *Lythrum Salicaria*, hitherto has been found in Australia. *Illustrative Genera:* — Lythrum, *Linn.*; Lawsonia, *Linn.* There are about 250 species.

Properties and Uses.—These plants are chiefly remarkable for the possession of an astringent principle, and for their value in dyeing.

Order 145. ONAGRACEÆ, the Evening Primrose Order.—Character.—*Herbs* or *shrubs. Leaves* alternate or opposite, simple, exstipulate, without dots. *Calyx* superior, tubular, with the limb usually 4-lobed, or sometimes 2-lobed; in æstivation valvate; or rarely the limb is absent. *Petals* usually large and showy, generally regular and equal in number to the divisions of the calyx, twisted in æstivation, and inserted into the throat of the calyx; rarely absent. *Stamens* definite, 2, 4, or 8, or rarely by abortion 1, inserted with the petals into the throat of the calyx; *filaments* distinct; *pollen* trigonal. *Ovary* inferior, 2—4-celled; *placentas* axile; *style* 1, filiform; *stigma* lobed or capitate. *Fruit* capsular, or succulent and indehiscent, 2—4-celled. *Seeds* numerous, without albumen; *embryo* straight.

Diagnosis.—Herbs or shrubs, with simple exstipulate dotless leaves. Calyx superior, 2—4-lobed, valvate in æstivation. Petals usually equal in number to the lobes of the calyx, with a twisted æstivation, or rarely absent. Stamens few, inserted into the throat of the calyx with the petals. Ovary inferior, 2—4-celled;

style simple; stigma lobed or capitate. Fruit dehiscent or indehiscent. Seeds numerous, without albumen.

Distribution and Numbers.—Chiefly natives of the temperate parts of North America and Europe; many are also found in India, but they are rare in Africa, except at the Cape. *Illustrative Genera*:—Œnothera, *Linn.*; Circæa, *Tourn.* There are about 300 species.

Properties and Uses.—Generally the plants are harmless and possess mucilaginous properties. The roots of *Œnothera biennis* and other species of the same genus are edible. The fruits of many *Fuchsias* are somewhat acid and good to eat. Some species of *Jussiæa* are astringent.

Cohort 3.—*Passiflorales.*

Order 146. SAMYDACEÆ, the Samyda Order.—Character. *Trees* or *shrubs*. *Leaves* alternate, simple, evergreen, stipulate, usually with round or linear transparent glands. *Calyx* inferior, 4–5-partite. *Petals* absent. *Stamens* perigynous, 2, 3, or 4 times as many as the divisions of the calyx; *filaments* united, some of them frequently without anthers; *anthers* 2-celled. *Ovary* superior, 1-celled; *style* 1, filiform; *placentas* parietal, bearing numerous ovules. *Fruit* capsular, leathery, 1-celled. *Seeds* numerous, arillate, with oily or fleshy albumen; *embryo* large.

Distribution and Numbers.—Exclusively tropical, and principally American. *Illustrative Genera*:—Samyda, *Linn.*; Casearia, *Jacq.* There are more than 100 species.

Properties and Uses.—Of little importance. They are commonly bitter and astringent.

Order 147. HOMALIACEÆ, the Homalium Order.—Character.—*Trees* or *shrubs*, with alternate leaves. *Calyx* superior, funnel-shaped, with from 5 to 15 divisions. *Petals* equal in number to, and alternate with, the divisions of the calyx. *Stamens* opposite to the petals and inserted on them, either distinct or in bundles of 3 or 6. *Ovary* inferior, 1-celled; *placentas* parietal; *ovules* numerous; *styles* 3–5. *Fruit* a capsule or berry. *Seeds* small; *embryo* in the axis of a little fleshy albumen. *This order is included in Samydaceæ by Bentham and Hooker.*

Distribution and Numbers.—They are natives of the tropical parts of India, Africa, and America. *Illustrative Genera*:—Homalium, *Jacq.*; Trimeria, *Harv.* There are about 36 species.

Properties and Uses.—Some species of *Homalium* are astringent, but nothing is known of the properties of the other genera.

Order 148. LOASACEÆ, the Chili Nettle Order.—Character. *Herbaceous plants*, with stiff hairs or stinging glands. *Leaves* exstipulate. *Calyx* superior, 4- or 5-parted, persistent. *Petals* 5 or 10, in 2 whorls, often hooded. *Stamens* numerous, in several whorls, either distinct or united in bundles. *Ovary* inferior, 1-celled, with several parietal placentas, or 1 axile placenta; *style* 1; *ovules* anatropous. *Fruit* capsular or succulent. *Seeds* with a loose testa, and having an embryo lying in the axis of fleshy albumen.

Distribution and Numbers.—They are all natives of North and South America. *Illustrative Genera*:—Bartonia, *Muehl.*; Loasa, *Adans.* There are about 70 species.

Properties and Uses.—Some of the species are remarkable for their stinging glands; hence their common name of Chili Nettles. Several species are cultivated on account of the beauty of their flowers. A Mexican species, *Mentzelia hispida*, is reputed to possess a purgative root.

Order 149. TURNERACEÆ, the Turnera Order.—Character.—*Herbaceous* or somewhat *shrubby* plants. *Leaves* alternate, exstipulate, hairy. *Flowers* axillary. *Calyx* inferior, 5-lobed, imbricate in æstivation. *Petals* 5, equal, twisted in æstivation, without a corona, perigynous, deciduous. *Stamens* 5, alternate with the petals, perigynous; *filaments* distinct. *Ovary* 1-celled, superior, with 3 parietal placentas; *styles* 3, more or less united at the base, forked or branched above. *Fruit* capsular, 1-celled, 3-valved, partially dehiscing in a loculicidal manner. *Seeds* with a caruncle on one side, and a slightly curved *embryo* in the midst of fleshy albumen.

Distribution and Numbers.—Natives exclusively of South America and the West Indies. *Illustrative Genera*:—Turnera, *Plum.*; Piriqueta, *Aubl.* There are about 60 species.

Properties and Uses.—Some are said to be astringent, others tonic and expectorant, and a few aromatic.

Order 150. PASSIFLORACEÆ, the Passion-flower Order.—Character.—*Herbs* or *shrubs*, usually climbing by tendrils, or rarely *trees*. *Leaves* alternate, with foliaceous or rarely minute stipules. *Flowers* perfect or very rarely unisexual. *Sepals* 5, united below into a tube, the throat of which bears a number of filamentous processes, thus forming a kind of corona; *petals* 5, inserted into the throat of the calyx on the outside

of the filamentous processes, with an imbricate æstivation; sometimes wanting. *Stamens* usually 5, monadelphous or rarely numerous, attached to the stalk of the ovary, and thus raised above the calyx. *Ovary* stalked, superior, 1-celled; *styles*, 3, clavate; *placentas* parietal. *Fruit* 1-celled, stalked, generally succulent. *Seeds* numerous, arillate; *embryo* in thin fleshy albumen.

Distribution and Numbers.—They are chiefly found in tropical America, but a few also occur in North America and the East Indies, and several in Africa. *Illustrative Genera:*—Passiflora, *Juss.*; Tacsonia, *Juss.* There are about 214 species.

Properties and Uses.—Several have edible fruits, and others are said to be bitter and astringent, narcotic, emmenagogue, or diaphoretic.

Order 151. MALESHERBIACEÆ, the Crownwort Order.—*Diagnosis.*—This is a small order of herbaceous or somewhat shrubby plants, resembling Passifloraceæ, *in which it is included by Bentham and Hooker*, but they differ in never being climbers; in the want of stipules; in the filamentous processes of the flowers of that order being reduced to a short membranous ring or coronet in this; in the insertion of the styles at the back instead of the apex of the ovary; and in the seeds not being arillate.

Distribution and Numbers.—They are all natives of Chili and Peru. *Illustrative Genera:*—Malesherbia, *R. et P.*; Gynopleura, *Cav.* These are the only genera; they include 5 species.

Properties and Uses.—Altogether unknown.

Order 152. PAPAYACEÆ, the Papaw Order.—Character.—*Trees* or *shrubs*, sometimes with an acrid milky juice. *Leaves* alternate, on long stalks, lobed. *Flowers* unisexual, or rarely perfect. *Calyx* inferior, minute, 5-toothed. *Corolla* gamopetalous, and usually without scales or filamentous corona in the female flowers; 5-lobed. The *male flower* has a few stamens inserted on the corolla. The *female flower* has a 1-celled superior ovary, with 3—5 parietal placentas. *Fruit* succulent or dehiscent. *Seeds* numerous, albuminous, with the radicle towards the hilum. *This order is included in Passifloraceæ by Bentham and Hooker.*

Distribution and Numbers.—Natives of South America and the warmer parts of the Old World. *Illustrative Genera:*—Carica, *Linn.*; Modecca, *Linn.* There are about 26 species.

Properties and Uses.—Generally unimportant; but the acrid

milky juice is said to be poisonous in some species, and emmenagogue in others. The seeds of some species are also emmenagogue.

Order 153. CUCURBITACEÆ, the Gourd Order.—Character.—*Herbs*, generally of a succulent nature, and either prostrate, or climbing by means of tendrils. *Leaves* succulent, alternate, with a radiate venation, more or less scabrous, exstipulate. *Flowers* unisexual, monœcious or diœcious. *Calyx* gamosepalous, 5-toothed, the limb sometimes obsolete, superior in the female flowers. *Corolla* gamopetalous, 4—5-parted, or of distinct valvate or induplicate petals, sometimes fringed, perigynous. *Male flower* :—*Stamens* usually 5, epipetalous, and alternate with the

FIG. 1111.

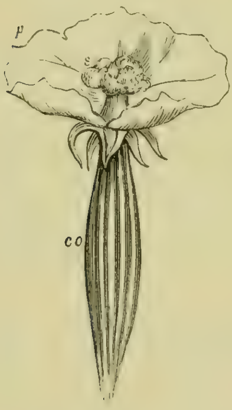


FIG. 1112.

Fig. 1111. Female or pistillate flower of the Cucumber (*Cucumis sativus*). *co*. Calyx adherent to the ovary; the limb is seen above, with five divisions. *p*. Corolla. *s*. Stigmas.——*Fig*. 1112. Male or staminate flower of the same, the floral envelopes of which have been divided in a longitudinal manner. From Jussieu. *c*. Calyx. *p*. Corolla. *st*. Stamens.

segments of the corolla, either distinct or monadelphous, or more frequently triadelphous in such a way that two of the bundles contain each 2 stamens, and the other but 1 stamen; rarely there are but 2 or 3 stamens present; *anthers* 2-celled, usually long and sinuous, or sometimes straight. *Female flower* :—*Ovary* inferior, 1-celled, or generally spuriously 3-celled from the projection inwards of the placentas; *placentas* parietal, usually 3, or rarely 2; *ovules* indefinite or sometimes solitary; *style* short; *stigmas* thickened, papillose, lobed or fringed. *Fruit* a pepo, or rarely a berry. *Seeds* more or less flattened, usually with a leathery or horny testa, which is enveloped in a succulent or membranous covering; generally

numerous, or rarely solitary; *embryo* flat, without albumen; *cotyledons* leafy; *radicle* towards the hilum.

Diagnosis.—Herbs, usually of a succulent nature, prostrate or climbing. Leaves rough, alternate, radiate-veined, exstipulate. Flowers unisexual. Calyx 5-toothed or obsolete, superior in the female flowers. Corolla perigynous. Male flower with usually 5 stamens, which are distinct, monadelphous, or triadelphous, and epipetalous; rarely there are but 2 or 3 stamens; anthers long and usually sinuous or sometimes straight. Female flower:—Ovary inferior, with parietal placentas; style short; stigmas more or less dilated. Fruit succulent. Seeds flat, generally numerous, exalbuminous, cotyledons leafy.

Division of the Order and Illustrative Genera.—The Cucurbitaceæ have been divided by Bentham and Hooker as follows:—

Series 1. PLAGIOSPERMEÆ.—Ovules horizontal. *Illustrative Genus*:—Bryonia, *Linn.*

Series 2. ORTHOSPERMEÆ.—Ovules erect or ascending. *Illustrative Genus*:—Trianosperma, *Torr. et Gr.*

Series 3. CREMOSPERMEÆ.—Ovules pendulous. *Illustrative Genera*:—Sicyos, *Linn.*; Sechium, *P. Br.*

Distribution and Numbers.—Natives principally of hot climates in almost every part of the world, but especially abundant in the East Indies. One species only, *Bryonia dioica*, occurs in the British Islands. There are about 360 species.

Properties and Uses.—An acrid bitter purgative property is the chief characteristic of the plants of this order; this is possessed more or less by all parts of the plant, but it is especially evident in the pulp surrounding the seeds; the seeds themselves are, however, usually harmless. In some plants this acridity is so concentrated that they become poisonous; while in other cases, and especially from cultivation, it is so diffused that their fruit is edible.

Order 154. BEGONIACEÆ, the Begonia Order.—Character.—*Herbs*, or low succulent *shrubs*. *Leaves* alternate, very unequal-sided at the base, with large membranous stipules. *Flowers* unisexual. *Perianth* coloured. *Male flower* with 4 *perianth-leaves*, 2 of which are smaller than the others, and decussating with them, are placed internally to them. *Stamens* numerous, distinct or united by their filaments into a column; *anthers* 2-celled, clavate, with longitudinal dehiscence, clustered. *Female flower* with 5 or 8 *perianth-leaves*. *Ovary* inferior, winged, 3-celled, with three large projecting placentas, meeting in the axis;

stigmas 3, sessile, 2-lobed. *Fruit* winged, capsular. *Seeds* numerous, with a thin reticulated testa, and without albumen.

Distribution and Numbers.—Natives chiefly of India, South America, and the West Indies. *Illustrative Genera* :—Begonia, *Linn.*; Diploclinium, *Lindl.* There are more than 160 species.

Properties and Uses.—They are generally reputed to possess astringent and bitter properties, and occasionally to be purgative.

Order 155. DATISCACEÆ, the Datisca Order.—Character.—*Herbs*, or in the case of *Tetrameles* a large *tree*. *Leaves* alternate, exstipulate. *Flowers* diclinous, apetalous. *Male flower* with a 3—4-cleft *calyx*. *Stamens* 3—7; *anthers* 2-celled, linear, bursting longitudinally. *Female flower* with a superior 3—4-

FIG. 1113.

FIG. 1114.

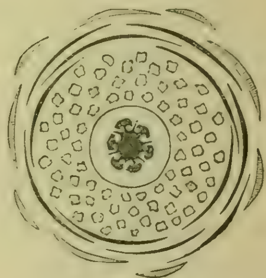


Fig. 1113. Vertical section of the flower of the Prickly Pear (*Opuntia vulgaris*). ——*Fig.* 1114. Diagram of the flower of the same.

toothed *calyx*, and a 1-celled *ovary*, with 3—4 polyspermous parietal *placentas*. *Fruit* dry, opening at the apex. *Seeds* without albumen, minute, numerous.

Distribution and Numbers.—They are widely distributed over the globe. *Illustrative Genera* :—Datisca, *Linn.*; Tetrameles, *R. Br.* The above are the only genera: there are 4 species.

Properties and Uses.—Of little importance.

Cohort 4.—*Ficoidales.*

Order 156. CACTACEÆ, the Cactus Order.—Character.—*Succulent plants*, which are usually spiny and leafless. *Stems* fleshy, globular, columnar, flattened, or 3- or more-angled, and

altogether presenting a peculiar and irregular appearance. *Flowers* solitary, sessile. *Sepals* and *petals* imbricate, usually numerous, in several whorls, and scarcely distinguishable from each other, or rarely 4-merous; adherent to the ovary (*fig.* 1113). *Stamens* numerous, with long *filaments* and versatile *anthers*. *Ovary* inferior, fleshy, 1-celled, with parietal placentas; *style* 1; *stigmas* several. *Fruit* succulent. *Seeds* numerous, without albumen.

Distribution and Numbers.—Natives almost exclusively of the tropical regions of America. *Illustrative Genera:*—Melocactus, *C. Bauhin*; Mammillaria, *Haw.* There are about 800 supposed species.

Properties and Uses.—The fruit of many species is somewhat acid and agreeable, and is useful in febrile complaints. The fleshy stems of the Melon Cactus (*Melocactus*) are eaten by cattle in the dry districts of South America on account of their juice. Many species of *Cereus*, *Epiphyllum*, &c., are cultivated on account of their showy flowers. Some species of *Cereus*, as *C. grandiflorus* and *C. nycticallus*, open their flowers at night; they are remarkable for their size, some being as much as 1 foot in diameter.

Order 157. MESEMBRYANTHACEÆ or FICOIDACEÆ, the Ice-plant Order.—Character.—*Succulent herbs* or *shrubs*, with opposite or alternate, simple, exstipulate leaves. *Calyx* 3—8-partite, either free or partially adherent to the ovary. *Petals* either numerous and showy, or altogether absent. *Stamens* perigynous or epigynous, distinct, numerous or definite. *Ovary* inferior or nearly superior, usually many-celled, rarely 1-celled; *placentas* axile, free central, or parietal; *styles* and *stigmas* as many as the cells of the ovary, distinct; *ovules* usually numerous or rarely solitary, amphitropous or anatropous. Fruit usually capsular and many-celled, or rarely 1-celled, dehiscing in a stellate or circumscissile manner at the apex, or splitting at the base; or woody and indehiscent. *Seeds* few or numerous, or rarely solitary; *embryo* curved or spiral, on the outside of mealy albumen.

Diagnosis.—Succulent herbs or shrubs, with simple exstipulate leaves. Sepals definite, generally more or less adherent to the ovary. Petals very numerous or absent. Stamens perigynous or nearly epigynous. Ovary inferior or nearly superior; styles distinct; placentas axile, free central, or parietal. Fruit capsular or indehiscent. Seeds with a curved or spiral embryo on the outside of mealy albumen.

Division of the Order and Illustrative Genera.—The Mesembryanthaceæ may be divided into three sub-orders as follows:—

Sub-order 1. MESEMBRYANTHEÆ.—Leaves opposite. Petals numerous, conspicuous. Stamens numerous. Fruit capsular, dehiscent. — *Illustrative Genera:* — Mesembryanthemum, *Linn.*; Lewisia, *Pursh.*

Sub-order 2. TETRAGONIEÆ.—Leaves alternate. *Petals* absent. Stamens definite. Fruit woody and indehiscent.—*Illustrative Genera:*—Tetragonia, *Linn.*; Aizoon, *Linn.*

Sub-order 3. SESUVIEÆ.—Leaves alternate. Petals absent. Stamens definite. Fruit capsular, with transverse dehiscence.—*Illustrative Genera:*—Sesuvium, *Linn.*; Cypselea, *Turp.*

The last two sub-orders are sometimes placed in an order by themselves, called *Tetragoniaceæ*, which is distinguished from the Mesembryanthaceæ by having alternate leaves, no petals, and definite stamens. The plants comprehended in the above three sub-orders are, however, so nearly allied, that we have, following Bentham and Hooker, placed them in one order as above. *The tribe Mollugineæ of Caryophyllaceæ is also placed in this order by Bentham and Hooker.*

Distribution and Numbers.—Natives exclusively of warm and tropical regions. A large number are found at the Cape of Good Hope. There are about 450 species.

Properties and Uses.—Several are edible; others yield an abundance of soda when burned; but generally the plants of the order are of little importance.

Cohort 5.—*Umbellales.*

Order 158. UMBELLIFERÆ, the Umbelliferous Order.—Character.—*Herbs*, *shrubs*, or very rarely small *trees*, with usually hollow or rarely solid stems. *Leaves* alternate, generally amplexicaul, usually compound, or sometimes simple, and always exstipulate. *Flowers* generally in umbels, which are usually compound, or sometimes simple; rarely the flowers are in capitula, with or without an involucre; the partial umbels or umbellules also with or without an involucel. *Calyx* superior, the limb entire, annular, or 5-toothed, or obsolete. *Petals* 5, usually inflexed at the point, often unequal in size, inserted on the calyx outside the disc which crowns the ovary; *æstivation* imbricate, or rarely valvate or induplicate. *Stamens* 5, inserted with the petals and

alternate with them; incurved in æstivation. *Ovary* inferior, crowned by a double fleshy disc (*stylopod*), 2-celled, with a solitary pendulous ovule in each cell; *styles* 2, *stigmas* simple. *Fruit* (*figs.* 1116–1118) a *cremocarp* consisting of 2 carpels (*mericarps*) adhering by their face (*commissure*) to a common axis (*carpophore*), which is undivided or forked, from which they

FIG. 1115.

FIG. 1116.

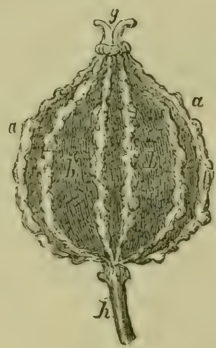


FIG. 1117.

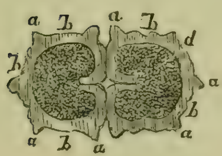


FIG. 1118.

Fig. 1115. *a.* General umbel of Fool's Parsley (*Æthusa Cynapium*) in fruit. *b.* One of the umbellules, showing the 3-leaved unilateral pendulous involucel.——*Fig.* 1116. A side view of the ripe fruit of Hemlock (*Conium maculatum*).——*Fig.* 1117. Transverse section of the fruit of the same.——*Fig.* 1118. Vertical section of one of the halves (*mericarps*) of the same fruit. The letters refer to the same parts in the last three figures. *a.* Ridges. *b.* Channels. *d.* Albumen. *f.* Embryo. *g.* Remains of the styles. *h.* Axis. *i.* Prolonged axis or carpophore.

ultimately separate and become pendulous; each mericarp is an indehiscent 1-seeded body, traversed on its dorsal surface by *ridges*, *a*, of which there are usually 5; but sometimes there are 4 others, alternating with them, in which case the former are termed *primary*, and the latter *secondary* ridges; sometimes the primary ridges are absent; the spaces between the ridges are

called channels (*valleculæ*), *b*; in the pericarp are frequently oil-receptacles called *vittæ*. *Seed* pendulous; *embryo* minute, *f*, at the base of abundant horny albumen, *d*; *radicle* pointing towards the hilum.

Diagnosis.—Herbs or shrubs. Stems generally hollow; leaves alternate, usually compound and amplexicaul, or sometimes simple, and always exstipulate. Flowers arranged in umbels, or rarely in capitula. Calyx superior, inconspicuous. Petals and stamens 5, inserted on the outside of a double fleshy epigynous disc. Ovary inferior, 2-celled, with a solitary pendulous ovule in each cell; styles 2. Fruit consisting of two indehiscent carpels, which separate when ripe from a common axis or carpophore. Each carpel bearing primary or secondary ridges, or both. Seeds pendulous, one in each carpel, with a minute embryo at the base of abundant horny albumen.

Division of the Order and Illustrative Genera:—The order has been divided into three sub-orders from the appearance of the albumen. but these are by no means well defined. They are as follows:—

Sub-order 1. ORTHOSPERMEÆ.—Albumen not curved. *Illustrative Genera:*—Hydrocotyle, *Linn.*; Œnanthe, *Linn.*; Heracleum, *Linn.*

Sub-order 2. CAMPYLOSPERMEÆ.—Albumen rolled inwards at the margins, and presenting a vertical furrow on its face. *Illustrative Genera:*—Anthriscus, *Hoffm.*; Chærophyllum, *Linn.*; Conium, *Linn.*

Sub-order 3. CŒLOSPERMEÆ.—Albumen with the base and apex curved inwards towards the axis. *Illustrative Genera:*—Ormosciadium, *Boiss.*; Coriandrum, *Linn.*

By Bentham and Hooker this order has been divided as follows:—

Series 1. HETEROSCIADIEÆ.—Umbels generally simple or very irregularly compound, or the inflorescence is a capitulum. Vittæ absent or obscure. *Illustrative Genera:*—Hydrocotyle, *Linn.*; Astrantia, *Linn.*; Eryngium, *Linn.*

Series 2. HAPLOZYGIEÆ.—Umbels compound. Primary ridges of fruit alone conspicuous. Vittæ usually, but not always, obvious. *Illustrative Genera:*—Conium, *Linn.*; Myrrhis, *Scop.*; Fœniculum, *Adanson.*

Series 3. DIPLOZYGIEÆ.—Umbels usually compound. Fruit with both primary and secondary ridges generally well marked. *Illustrative Genera:*—Caucalis, *Linn.*; Daucus, *Linn.*

Distribution and Numbers.—Chiefly natives of the northern parts of Europe, Asia, and America. Many occur, however, in the southern hemisphere. They are rare in tropical regions except upon the mountains, where they are by no means uncommon. There are about 1,400 species.

Properties and Uses.—Extremely variable: thus, some are edible; others aromatic and carminative, and, in some cases, stimulant and tonic, from the presence of a volatile oil; some, again, contain a narcotico-acrid juice, which renders them more or less poisonous; while others are antispasmodic and stimulant from the presence of a more or less fœtid gum-resin, which is essentially composed of gum, resin, and volatile oil. This oil in the case of Asafœtida contains sulphur.

Fig. 1119.

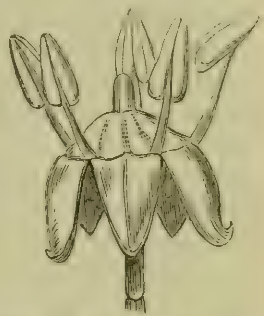


Fig. 1119. Flower of the common Ivy (*Hedera Helix*).

Order 159. Araliaceæ, the Ivy Order.—Character.—*Trees, shrubs*, or *herbs*. *Leaves* alternate, exstipulate. *Flowers* generally in umbels or capitula, usually perfect or rarely unisexual. *Calyx* more or less superior, entire or toothed. *Petals* 2, 4, 5, 10, deciduous, almost always valvate in æstivation or rarely imbricate, generally distinct or rarely gamopetalous; occasionally wanting. *Stamens* corresponding in number to the petals and alternate with them, or twice as many, inserted on the outside of a disc which crowns the ovary; *anthers* introrse, versatile, with longitudinal dehiscence. *Ovary* more or less inferior, usually with more than 2 cells, or very rarely 1-celled, crowned by a disc; each cell with a solitary pendulous anatropous ovule; *styles* as many as the cells, sometimes united; *stigmas* simple. *Fruit* usually 3- or more-celled, succulent or dry, each cell with 1 pendulous seed, with fleshy albumen.

Diagnosis.—Closely allied to Umbelliferæ, from which it may be distinguished by the valvate æstivation of the corolla; and by the fruit being usually 3- or more-celled, the carpels of which do not separate when ripe from a carpophore. There is also a greater tendency among Araliaceæ to form a woody stem than in Umbelliferæ.

Distribution and Numbers.—These plants are universally distributed, being found in tropical, subtropical, temperate, and the coldest regions. *Illustrative Genera*:—Panax, *Linn.*; Hedera, *Linn.* The order includes about 300 species.

Properties and Uses.—Generally stimulant, aromatic, diaphoretic, and somewhat tonic.

Order 160. CORNACEÆ, the Dogwood Order.—Character.—*Shrubs*, *trees*, or rarely *herbs*. *Leaves* simple, opposite or very rarely alternate, exstipulate. *Flowers* perfect or rarely unisexual, arranged in heads, or in a corymbose or umbellate manner, with or without an involucre. *Calyx* superior, 4-lobed. *Petals* 4, broad at the base, inserted at the top of the calyx-tube; *æstivation* valvate. *Stamens* 4, inserted with the petals and alternate to them. *Ovary* inferior, surmounted by a disc; usually 2-celled; *ovule* pendulous, solitary, anatropous; *style* and *stigma* simple. *Fruit* drupaceous, crowned with the remains of the calyx. *Seed* pendulous; *embryo* in the axis of fleshy albumen.

Diagnosis.—Trees, shrubs, or rarely herbs, with simple exstipulate, and (with but one exception) opposite leaves. Flowers perfect, or sometimes unisexual. Calyx superior, 4-lobed. Corolla with 4 petals, and a valvate æstivation. Stamens 4, alternate with the petals. Ovary inferior, surmounted by a disc; usually 2-celled, with a single pendulous anatropous ovule in each cell; style and stigma simple. Fruit drupaceous. Embryo in the axis of fleshy albumen.

Distribution and Numbers.—Natives of the temperate parts of Europe, Asia, and America. *Illustrative Genera*:—Cornus, *Linn.*; Aucuba, *Thunb.* There are more than 70 species.

Properties and Uses.—The plants of this order are chiefly remarkable for tonic, febrifugal, and astringent properties.

Order 161. GARRYACEÆ, the Garrya Order.—Character. Evergreen *shrubs*. *Leaves* opposite, exstipulate. *Flowers* unisexual, apetalous, amentaceous. *Male flower* with 4 *sepals*, and *stamens* alternating with them. *Female flower* with a superior 2-toothed *calyx*, and 1—3-celled *ovary* with 2 styles, and 2 pendulous stalked ovules. *Fruit* indehiscent, baccate, 2-seeded. *Seeds* with a very minute embryo in abundant albumen. *By Bentham and Hooker this order is included in Cornaceæ.*

Distribution and Numbers.—Natives of the temperate parts of North America, or of the West Indies. *Illustrative Genera*:—Garrya, *Dougl.*; Fadgenia, *Endl.* These are the only genera; they include 6 species.

Properties and Uses.—But little is known of the properties of these plants; but *Garrya Fremontii*, a native of California, is known as the Quinine Bush from its leaves being used in fevers and ague.

Order 162. ALANGIACEÆ, the Alangium Order.—Character. *Trees* or *shrubs*. *Leaves* alternate, entire, exstipulate, without dots. *Calyx* superior, 5—10-toothed. *Petals* 5—10, linear, reflexed. *Stamens* equal in number to, or twice or four times as numerous as, the petals; *anthers* adnate. *Ovary* inferior, 1—2-celled; *style* simple, *ovule* solitary, pendulous. *Fruit* drupaceous, more or less united to the calyx, 1-celled. *Seed* solitary, pendulous, with fleshy albumen, and large flat leafy cotyledons.

Distribution and Numbers.—Natives of various parts of the East Indies and the United States. *Illustrative Genera*:—Alangium, *Lam.*; Nyssa, *Linn.* There are about 8 species. *By Bentham and Hooker they are included in Cornaceæ.*

Properties and Uses.—Of little importance. Some species of *Alangium* are said to be purgative and aromatic; and their succulent fruits are also edible. The fruit of *Nyssa capitata* or *N. candicans* is used occasionally as a substitute for Lime fruit, whence it is called the *Ogechee Lime*.

Artificial Analysis of the Orders in the Sub-class Polypetalæ.

Series 3. CALYCIFLORÆ.

1. FLOWERS with more than 20 stamens.

A. Ovary wholly superior.

a. *Leaves without stipules.*

1. *Carpels more or less distinct (at least as to the styles); or solitary.*
   Stamens distinctly perigynous. Ovules suspended, erect, or ascending . . . *Rosaceæ (part).*
2. *Carpels wholly combined (at least as to the ovaries).*
   Sepals more than 2, united into a tube. Ovary with axile placentas . . . *Lythraceæ (part).*

b. *Leaves with stipules.*

1. *Carpels more or less distinct (at least as to the styles); or solitary.*
   Calyx with the odd lobe inferior. Stamens somewhat hypogynous . . . . *Leguminosæ (Mimosæ).*
   Calyx with the odd lobe superior. Stamens distinctly perigynous . . . . *Rosaceæ.*
2. *Carpels wholly combined (at least as to the ovaries).*
   Leaves with circinate vernation. Placentas parietal . . . . *Droseraceæ.*

B. Ovary inferior, or partially so.

a. *Leaves without stipules.*

1. *Placentas parietal.*

Petals definite in number, distinct from the calyx . . . . *Loasaceæ.*

Petals indefinite in number, gradually passing into the sepals . . . . . *Cactaceæ.*

2. *Placentas in the axis.*

Leaves with transparent dots.

Ovary 1-celled . . . . . . *Chamælauciaceæ.*

Ovary with more than one cell . . . *Myrtaceæ.*

Leaves without dots.

Petals very numerous . . . . *Mesembryanthaceæ.*

Petals definite in number.

Petals narrow and strap-shaped . . *Alangiaceæ.*

Petals roundish and concave.

Styles united . . . . . *Barringtoniaceæ.*

Styles distinct . . . . . *Philadelphaceæ.*

b. *Leaves with stipules.*

1. *Carpels more or less distinct, or solitary* . *Rosaceæ* (*part*).

2. *Carpels wholly combined* (*at least as to the ovaries*).

Leaves opposite . . . . . . *Rhizophoraceæ.*

Leaves alternate.

Placentas axile . . . . . *Lecythidaceæ.*

Placentas parietal . . . . . *Homaliaceæ.*

2. Flowers with fewer than 20 stamens.

A. Ovary wholly superior.

a. *Leaves without stipules.*

1. *Carpels more or less distinct, or solitary.*

Carpels with hypogynous scales.

Each carpel having one scale . . . *Crassulaceæ.*

Each carpel having two scales . . . *Francoaceæ.*

Carpels without hypogynous scales.

Carpels solitary, or all but one imperfect.

Leaves without dots.

Ovules collateral, ascending, sessile . *Connaraceæ.*

2. *Carpels more or less combined* (*at least by their ovaries*).

Placentas parietal.

Flowers with a ring or crown.

Flowers unisexual . . . . . . *Papayaceæ.*

Flowers hermaphrodite . . . . *Malesherbiaceæ.*

Flowers without a ring or crown . . *Turneraceæ.*

Placentas in the axis.

Styles distinct to the base.

Carpels each with one hypogynous scale *Crassulaceæ.*
Carpels without hypogynous scales . *Saxifragaceæ (part).*
Styles more or less combined.
Calyx imbricate. Ovules suspended . *Bruniaceæ.*
Calyx valvate.
Leaves simple. Calyx tubular . . *Lythraceæ.*

b. *Leaves with stipules.*

1. *Carpels distinct, or solitary.*

Fruit leguminous; odd lobe of the calyx inferior . . . . *Leguminosæ.*
Fruit not leguminous: odd lobe of the calyx superior . . . . *Rosaceæ.*

2. *Carpels more or less combined (at least by their ovaries).*

Placentas parietal.
Flowers with a ring of appendages . *Passifloraceæ.*
Placentas in the axis.
Styles distinct to the base.
Petals conspicuous.
Leaves opposite . . . . . *Cunoniaceæ.*
Leaves alternate . . . . . *Saxifragaceæ (part).*

B. Ovary inferior, or partially so.

a. *Leaves without stipules, or with cirrhose appendages.*

Placentas parietal.
Flowers completely unisexual. Gamopetalous . . . . *Cucurbitaceæ.*
Flowers hermaphrodite or polygamous.
Petals distinct . . . . . *Ribesiaceæ.*
Placentas in the axis.
Flowers in umbels, or capitula.
Styles two . . . . *Umbelliferæ.*
Styles three or more . . . . . *Araliaceæ.*
Flowers not in umbels.
Carpel solitary.
Petals strap-shaped, reflexed . . . *Alangiaceæ.*
Petals oblong.
Cotyledons convolute . . . . *Combretaceæ.*
Cotyledons flat . . . . . *Haloragaceæ.*
Carpels two or more, divaricating at the apex.
Leaves alternate. Herbs . . . *Saxifragaceæ (part).*
Leaves opposite. Shrubs . . . *Hydrangeaceæ*

Carpels two or more, not divaricating, combined.
Calyx valvate, or the limb obsolete.
Stamens alternate with the petals if isomerous.
Albumen none. Ovules horizontal or ascending . . . . . *Onagraceæ.*
Albumen present. Ovules pendulous . . . . . . *Haloragaceæ.*
Albumen abundant. Flowers conspicuous . . . . . *Cornaceæ.*
Calyx not valvate.
Stamens doubled downwards. Anthers with appendages. Leaves ribbed *Melastomaceæ.*
Stamens only curved. Anthers short.
Leaves dotted . . . . . *Myrtaceæ.*
Leaves not dotted.
Seeds very numerous, minute . *Escalloniaceæ.*
Seeds few . . . . . *Bruniaceæ.*

b. *Leaves with stipules.*

Placentas parietal.
Stipules cirrhose. Gamopetalous . . . . *Cucurbitaceæ.*
Stipules deciduous. Petals distinct . . *Homaliaceæ*
Placentas in the axis.
Stamens, if equal to the petals, alternate with them.
Leaves opposite . . . . . . *Rhizophoraceæ.*
Leaves alternate . . . . . *Hamamelidaceæ.*

Although it generally happens that the Calycifloræ have dichlamydeous flowers, polypetalous corollas, and perigynous or epigynous stamens, yet many exceptions occur, which should be particularly noted by the student. Thus, we find apetalous plants in the *Leguminosæ*, *Rosaceæ*, *Saxifragaceæ*, *Cunoniaceæ*, *Crassulaceæ*, *Hamamelidaceæ*, *Haloragaceæ*, *Callitrichaceæ*, *Rhizophoraceæ*, *Combretaceæ*, *Samydaceæ*, *Loasaceæ*, *Datiscaceæ*, *Mesembryanthaceæ*, *Araliaceæ*, *Garryaceæ*, *Myrtaceæ*, *Lythraceæ*, *Onagraceæ*, *Passifloraceæ*. Gamopetalous corollas occur in some *Papayaceæ*, *Cucurbitaceæ*, *Belvisiaceæ*, *Crassulaceæ*, *Droseraceæ*, *Bruniaceæ*, *Melastomaceæ*, *Turneraceæ*, *Cactaceæ*, *Lecythidaceæ*, *Araliaceæ*. In some Calycifloræ, again, the stamens are wholly or in part hypogynous or nearly so, as in some *Connaraceæ*, *Leguminosæ*, *Saxifragaceæ*, *Crassulaceæ*, *Francoaceæ*.

Unisexual flowers occur as a rule in *Callitrichaceæ*, *Papayaceæ*, *Garryaceæ*, and *Cucurbitaceæ*, and sometimes in *Rosaceæ*, *Hydrangeaceæ*, *Passifloraceæ*, *Ribesiaceæ*, *Haloragaceæ*, *Combretaceæ*, *Cornaceæ*, *Hamamelidaceæ*, and *Araliaceæ*.

Synopsis of the British Natural Orders in the Series Calycifloræ.

A. Corolla polypetalous. Ovary superior.

1. Ovaries many, distinct or united, each with a style; or solitary with one lateral placenta.
   - Corolla regular.
     - Sepals combined below.
       - Stamens equal to or double the number of the petals; no stipules . . . *Crassulaceæ.*
       - Stamens 20 or more, perigynous. Leaves stipulate . . . . . . *Rosaceæ.*
   - Corolla irregular.
     - Leaves with stipules. Stamens mono- or diadelphous . . . . *Leguminosæ.*
2. Ovary solitary, with parietal placentation.
   - Corolla regular. Sepals equal, free, imbricate. Stamens 5 . . . . *Droseraceæ.*
3. Ovary solitary, with central placentas.
   - Calyx valvate in the bud.
     - Stamens inserted in the calyx tube below the petals . . . . *Lythraceæ.*

B. Corolla polypetalous, ovary partly or wholly inferior.

1. Ovary 1-celled. Placentas 2, parietal. Ovules numerous . . . . *Ribesiaceæ.*
2. Ovary 2—many-celled. Placentas central.
   - Stamens as many as the petals, or twice as many.
     - Petals imbricate in the bud.
       - Petals 5. Stamens 5. Flowers in umbels *Umbelliferæ.*
       - Petals 4—5. Ovary only partially inferior. Capsule 2-valved . . . . . . *Saxifragaceæ*
       - Petals 4. Stamens 4—8. Fruit, 4 nuts . *Haloragaceæ.*
     - Petals valvate in the bud.
       - Fruit a berry. Styles more than 2; leaves alternate . . . . *Araliaceæ.*
       - Fruit a drupe. Style 1; leaves opposite *Cornaceæ.*
       - Fruit a cremocarp . . . . . . *Umbelliferæ.*
     - Petals twisted in the bud.
       - Sepals valvate . . . . *Onagraceæ.*

C. Corolla gamopetalous.

Flowers unisexual . . . . *Cucurbitaceæ.*

D. Corolla wanting.

Flowers monœcious. Stamens solitary. Ovary 4-celled . . . . *Callitrichaceæ.*

Sub-Class III.—Gamopetalæ or Corollifloræ.

Series 1.—*Inferæ or Epigynæ.*

Cohort 1.—*Rubiales.*

Order 163. Caprifoliaceæ, the Honeysuckle Order.—Character.—Small *trees*, *shrubs*, or rarely *herbs*. *Leaves* opposite, usually exstipulate. *Calyx* superior, 4—5-cleft. *Corolla* gamopetalous, 4—5-cleft, tubular or rotate, regular or irregular, rarely polypetalous. *Stamens* 4—5, inserted on the corolla, and alternate with its lobes. *Ovary* inferior, 1—6-celled, often with 1 ovule in one cell, and several in the others, pendulous, or suspended; *style* filiform or absent; *stigmas* 1—3 or 5. *Fruit* indehiscent, 1- or more-celled, dry or succulent, and crowned by

Fig. 1121.

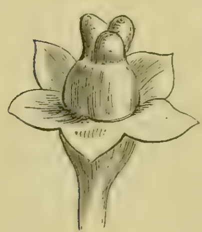


Fig. 1122.

Fig. 1123.

Fig. 1121. Pistil of the common Elder (*Sambucus nigra*) surrounded by a superior 5-lobed calyx.——*Fig.* 1122. Entire flower of the same.——*Fig.* 1123. Vertical section of the seed.

the persistent calyx lobes. *Seeds* solitary or numerous; *embryo* small, in fleshy albumen.

Diagnosis.—Small trees, shrubs, or rarely herbs, with opposite usually exstipulate leaves. Calyx superior, 4—5-cleft, persistent. Corolla gamopetalous, and bearing commonly as many stamens as it has lobes, to which they are alternate; regular or irregular. Ovary inferior, 1—6-celled. Fruit indehiscent. Seeds with fleshy albumen.

Distribution and Numbers.—Chiefly natives of the northern parts of Europe, Asia, and America. They are rare in the southern hemisphere. *Illustrative Genera* :—Lonicera, *Linn.*; Viburnum, *Linn.*; Sambucus, *Linn.* There are about 220 species.

Properties and Uses.—The plants of this order have fre-

quently showy flowers, which are also commonly sweet-scented; hence many are cultivated in our gardens and shrubberies, as Honeysuckles, which are species of *Caprifolium* and *Lonicera*; Guelder Roses (*Viburnum Opulus*), Laurustinus (*Viburnum Tinus*), Snowberry (*Symphoricarpus racemosus*), &c. Some are emetic and purgative; others astringent, sudorific, or diuretic; and some are acrid.

Order 164. RUBIACEÆ, the Madder Order.—Character.—*Trees*, *shrubs*, or *herbs*. *Stems* rounded or angular. *Leaves* simple, entire, and either opposite and with interpetiolar stipules, or whorled and exstipulate. (*The view is commonly held that the whorls of apparent leaves are in reality partly formed of leaves and partly of stipules, which resemble the true leaves in*

FIG. 1124.

FIG. 1125.

FIG. 1126.

FIG. 1127.

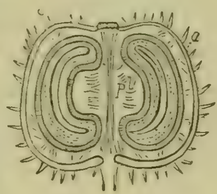


Fig. 1124. Diagram of the flower of the Madder (*Rubia tinctorúm*).——*Fig.* 1125. Pistil of the Madder, with its ovary adherent to the calyx, *cal.* *st.* Styles and stigmas.——*Fig.* 1126. Pistil of the Goose-grass or Cleavers (*Galium Aparine*) adherent to the calyx, *b*, by its ovary. *st.* Styles.——*Fig.* 1127. Vertical section of the fruit and seeds of the same. *a.* Albumen. *c.* Embryo. *pl.* Placenta.

appearance.) *Inflorescence* cymose. *Calyx* superior, with the limb 4—6-toothed or entire, or obsolete. *Corolla* epigynous, gamopetalous, regular, tubular or rotate, with its lobes corresponding in number to the teeth of the calyx when the latter is divided; *æstivation* valvate. *Stamens* inserted upon the corolla and equal in number to, and alternate with, its lobes. *Ovary* inferior, crowned by a disc, usually 2-celled or sometimes more; *style* 1 or 2, *stigma* simple or divided. *Fruit* inferior, 2-celled or rarely more, dry or succulent, indehiscent or separating into two or more dry cocci. *Seeds* 1, 2, or more, in each cell; when few they are erect or ascending, or when numerous, then attached to axile placentas; *embryo* small, in horny albumen (*fig.* 1127, *a*).

Diagnosis.—Trees, shrubs, or herbs, with opposite simple entire leaves, interpetiolar stipules, and rounded stems; or with whorled exstipulate leaves, and angular stems. Calyx superior.

Corolla regular, epigynous, with its lobes valvate. Stamens equal in number to the teeth of the calyx and segments of the corolla, with the latter of which they are alternate, epipetalous. Ovary inferior, 2- or more-celled, with an epigynous disc; ovules anatropous. Fruit inferior. Seeds 1 or more in each cell, with horny albumen.

Division of the Order and Illustrative Genera.—This order was separated by Lindley into two orders, the *Cinchonaceæ* and the *Galiaceæ* or *Stellatæ.* The Galiaceæ of Lindley were more especially distinguished from the Cinchonaceæ by their whorled exstipulate leaves and angular stems. The order Rubiaceæ is

Fig. 1128.

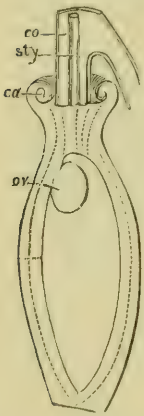


Fig. 1129.

Fig. 1130.

Fig. 1128. Vertical section of the ovary, &c., of the Red Valerian (*Centranthus ruber*). *ca.* Calyx. *co.* Corolla. *sty.* Style. *ov.* Ovule.——*Fig.* 1129. Fruit of *Scabiosa purpurea* (*Dipsaceæ*), surmounted by the pappose calyx. ——*Fig.* 1130. One of the central florets of the capitulum of *Scabiosa purpurea*, with the ovary, &c., cut vertically.

now divided by Hooker and Bentham into three series, each of which is again divided into sub-series and tribes. The Galiaceæ of Lindley are natives of the northern parts of the northern hemisphere and the mountains of the southern; while the Cinchonaceæ are almost exclusively natives of tropical and warm regions. There are about 3,000 species in the Rubiaceæ as defined above. *Illustrative Genera* :—Galium, *Linn.*; Cinchona, *Linn.*; Ixora, *Linn.*

Properties and Uses.—The properties of the plants of this extensive order are very important. Many possess tonic, febrifugal, astringent, emetic, or purgative properties; some are

diuretic and emmenagogue; a few are valuable dyeing and tanning agents; and others have edible fruits and seeds. Some are reputed to possess intoxicating, and in rare cases even poisonous, properties.

Cohort 2.—*Asterales.*

Order 165. VALERIANACEÆ, the Valerian Order.—Character.—*Herbs. Leaves* opposite, exstipulate. *Flowers* cymose, hermaphrodite or rarely unisexual. *Calyx* superior, with the limb obsolete, membranous, or pappose. *Corolla* epigynous, gamopetalous, tubular, imbricate, 3—6-lobed, regular or irregular, sometimes spurred at the base. *Stamens* 1—5, distinct, fewer than the lobes of the corolla, and inserted in its tube. *Ovary* inferior, with 1 fertile cell, and usually 2 abortive or empty ones. *Fruit* dry and indehiscent, frequently crowned by a pappus. *Seed* solitary, suspended, exalbuminous; *radicle* superior.

Distribution and Numbers.—Chiefly natives of the temperate parts of Europe, Asia, and America; they are rare in Africa. *Illustrative Genera:*—Centranthus, *DC.*; Valeriana, *Linn.* There are about 190 species.

Properties and Uses.—They are chiefly remarkable for the presence of a strong-scented volatile oil, which renders them stimulant, antispasmodic, and tonic. Some are highly esteemed in the East as perfumes, but they are not generally considered agreeable by Europeans.

Order 166. DIPSACEÆ, the Teazel Order.—Character.—*Herbs* or *undershrubs. Leaves* opposite or verticillate, exstipulate. *Flowers* in dense heads (capitula), surrounded by an involucre. *Calyx* superior, with a membranous or pappose limb, and surrounded by an involucel. *Corolla* tubular, epigynous, gamopetalous, the limb 4—5-lobed, generally irregular, and with an imbricate æstivation. *Stamens* 4, epipetalous; *anthers* distinct. *Ovary* inferior, 1-celled; *ovule* solitary, pendulous; *style* and *stigma* simple. *Fruit* dry, indehiscent, and surmounted by the pappose calyx. *Seed* with fleshy albumen; *embryo* straight; *radicle* superior.

Distribution and Numbers.—Chiefly natives of the South of Europe, and of North and South Africa. A few species are found in this country. *Illustrative Genera:*—Dipsacus, *Tourn.*; Scabiosa, *Linn.* There are about 170 species.

Properties and Uses.—Some are reputed to possess astringent and febrifugal properties, but as remedial agents they are alto-

gether unimportant. *Dipsacus Fullonum* is, however, an important economical species.

Order 167. CALYCERACEÆ, the Calycera Order.—Character.—*Herbs.*—*Leaves* alternate, exstipulate. *Flowers* in capitula, surrounded by an involucre. *Calyx* superior, irregular, 5-lobed. *Corolla* epigynous, gamopetalous; regular, valvate, 5-lobed. *Stamens* 5, epipetalous; *filaments* monadelphous; *anthers* partially united. *Ovary* inferior, 1-celled; *ovule* solitary, pendulous. *Fruit* indehiscent. *Seed* solitary, pendulous, with fleshy albumen; *radicle* superior.

Diagnosis.—These plants hold an intermediate position between Dipsaceæ and Compositæ, being distinguished from the former by their alternate leaves, absence of involucel to their individual florets, valvate æstivation of corolla, monadelphous filaments, and partially united anthers; and from the Compositæ in their anthers being only partially united, and in their pendulous albuminous seed, and superior radicle.

Distribution and Numbers.—Exclusively natives of South America, especially the cooler parts. *Illustrative Genera*:—Calycera, *Cavan.*; Leucocarpus, *Don.* There are about 20 species.

Properties and Uses.—Unknown.

Order 168. COMPOSITÆ, the Composite Order.—Character. *Herbs* or *shrubs*. *Leaves* alternate or opposite, exstipulate. *Flowers* (florets) hermaphrodite, unisexual, or neuter, arranged in capitula, which are commonly surrounded by an involucre formed of a number of imbricate bracts (*phyllaries*); the separate florets are also frequently furnished with membranous or scale-like bractlets (*paleæ*). *Capitula* developing sucessively in a centrifugal order. *Calyx* superior, its limb either entirely abortive or membranous; in the latter case it is entire, toothed, or pappose—that is, divided into bristles, or simple, branched, or feathery hair-like processes. *Corolla* epigynous, gamopetalous, tubular, ligulate, or bilabiate, 4—5-toothed, with a valvate æstivation. *Stamens* 5 or rarely 4, inserted on the corolla, and alternate with its divisions; *filaments* distinct or monadelphous; *anthers* united into a tube (*syngenesious*), which is perforated by the style and stigmas. *Ovary* inferior, bicarpellary, 1-celled, with 1 erect ovule; *style* 1, undivided below, and commonly bifid above; *stigmas* 2, one being usually placed on the inner surface or margin of each division of the style. *Fruit* a cypsela, dry, indehiscent, 1-celled,

crowned by the limb of the calyx, which is often pappose. *Seed* solitary, erect, exalbuminous ; *radicle* inferior.

Diagnosis.—Herbs or shrubs, with exstipulate leaves. Flowers (called florets) arranged in capitula, which are commonly surrounded by an involucre. Capitula developed successively in a centrifugal manner. Calyx superior, its limb abortive, or membranous, or pappose. Corolla epigynous, gamopetalous, 4–5-toothed, with a valvate æstivation. Stamens

FIG. 1131. FIG. 1132. FIG. 1133. FIG. 1134.

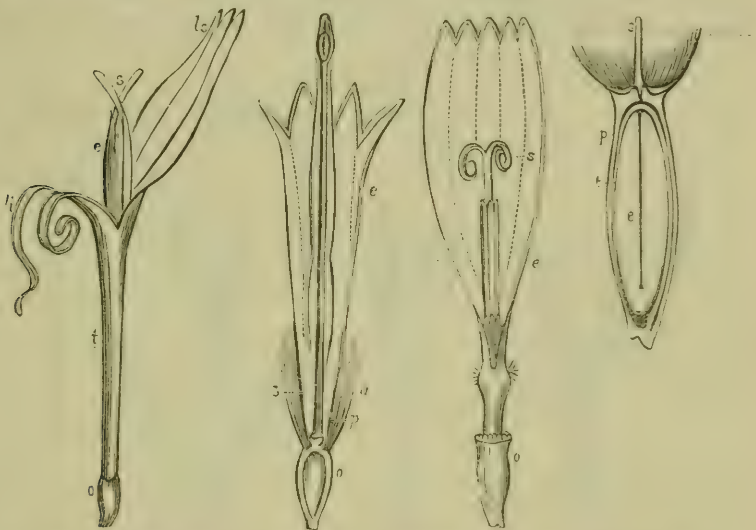


Fig. 1131. Labiate floret of *Chælanthera linearis*. *o.* Ovary with adherent calyx. *t.* Tube of the corolla. *l s.* Upper lip of the corolla. *l i.* Lower lip. *e.* Tube formed by the united anthers. *s.* Stigmas.——*Fig.* 1132. Vertical section of the floret of *Aster rubricaulis*. *o.* Ovary containing one erect ovule. *a.* Pappose limb of the calyx. *p.* Corolla. *s.* Style. *e.* Tube formed by the united anthers.——*Fig.* 1133. Floret of the chicory (*Cichorium Intybus*). *o.* Ovary with adherent calyx. *e.* Tube formed by the united anthers. *s.* Stigmas.——*Fig.* 1134. Vertical section of the ripe fruit of the Groundsel (*Senecio*), surmounted by a portion of the style, *s* ; and the pappose limb of the calyx. *p.* Pericarp. *t.* Testa. *e.* Seed. The above figures are from Jussieu.

epipetalous, equal in number to the divisions of the corolla (generally 5), and alternate with them ; anthers syngenesious. Ovary inferior, 1-celled, with 1 erect ovule ; style simple, bifid above, with stigmatic branches. Fruit 1-celled, dry, indehiscent. Seed solitary, erect, exalbuminous ; radicle inferior.

Division of the Order and Illustrative Genera.—This order has been variously divided by authors. By Linnæus, the plants of his class Syngenesia, division Polygamia (which

corresponded to the Natural Order Compositæ as above defined), were arranged in five orders, under the names of *Polygamia æqualis*, *P. superflua*, *P. frustranea*, *P. necessaria*, and *P. segregata*. Jussieu separated the Compositæ into three sub-orders as follows:—1. *Corymbiferæ*, the plants of which have either all tubular and perfect florets; or those of the disc tubular and perfect, and those of the ray tubular or ligulate and pistilliferous (radiant). 2. *Cynarocephalæ*, the florets of which are all tubular and perfect; or those of the disc perfect, and those of the ray neuter. And 3. *Cichoraceæ*, having all the florets ligulate and perfect. A fourth sub-order was afterwards added,

Fig. 1135.

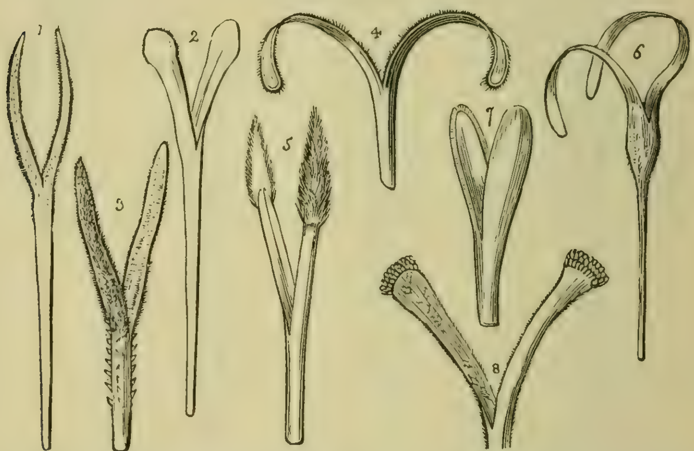


Fig. 1135. Styles and stigmas of composite flowers to illustrate De Candolle's tribes, after Heyland and Lindley. 1. *Albertinia erythropappa* (Vernonieæ). 2. *Anisochæta mikanioides* (Eupatorieæ). 3. *Blumea senecioides* (Asteroideæ). 4. *Menderia bicolor* (Senecioideæ). 5. *Lipochæta umbellata* (Senecioideæ). 6. *Aplotaxis nepalensis* (Cynareæ). 7. *Leucomeris spectabilis* (Mutisieæ). 8. *Leuceria tenuis* (Nassauvieæ).

called *Labiatifloræ*, which includes those plants the florets of which were bilabiate, and which were unknown to Jussieu. The arrangement most frequently adopted at the present day is that of De Candolle; this was founded on that of Lessing. It is as follows:—

Sub-order 1. Tubulifloræ.—Florets all tubular and perfect; or those of the centre (*disc*) are tubular, and alone perfect, while those of the circumference (*ray*) are tubular or ligulate, and pistillate or neuter; juice watery. This sub-order includes the Corymbiferæ and Cynarocephalæ of Jussieu. It has been divided into five tribes as follows:—

Tribe 1. *Vernonieæ.*—Style cylindrical; its arms generally long and subulate, sometimes short and blunt, always covered all over with bristles. *Illustrative Genera*:—Vernonia, *Schreb.*; Elephantopus, *Linn.*

Tribe 2. *Eupatorieæ.*—Style cylindrical; its arms long and somewhat clavate, with a papillose surface on the outside near the end. *Illustrative Genera*:—Eupatorium, *Tourn.*; Tussilago, *Tourn.*

Tribe 3. *Asteroideæ.*—Style cylindrical; its arms linear, flat on the outside, equally and finely downy on the inside. *Illustrative Genera*:—Erigeron, *Linn.*; Bellis, *Linn.*

Tribe 4. *Senecioideæ.*—Style cylindrical, its arms linear, fringed at the point, generally truncate, but sometimes extended beyond the fringe into a short cone or appendage of some kind. *Illustrative Genera*:—Anthemis, *Linn.*; Senecio, *Linn.*

The above four tribes correspond to the sub-order Corymbiferæ of Jussieu; the next or fifth tribe to the Cynarocephalæ of the same author.

Tribe 5. *Cynareæ.*—Style thickened above, and often with a bunch or fringe of hairs at the enlarged portion; its branches united or free. *Illustrative Genera*:—Arctium, *Linn.*; Centaurea, *Linn.*

Sub-order 2. LABIATIFLORÆ.—Florets with bilabiate corollas, perfect or unisexual. Juice watery. Of this sub-order we have two tribes:—

Tribe 6. *Mutisieæ.*—Style cylindrical or somewhat swollen; its arms usually blunt or truncate, very convex on the outside, and either covered at the upper part by a fine uniform hairiness, or absolutely free from hairs. *Illustrative Genera*:—Mutisia, *Linn. fil.*; Printzia, *Cass.*

Tribe 7. *Nassauvieæ.*—Style never swollen; its arms long, linear, truncate, and fringed only at the point. *Illustrative Genera*:—Nassauvia, *Juss.*; Trixis, *R. Br.*

Sub-order 3. LIGULIFLORÆ.—Florets all ligulate and perfect. Juice milky. This corresponds to the Cichoraceæ of Jussieu.

Tribe 8. *Cichoreæ.*—Style cylindrical at the upper part; its arms somewhat obtuse, and equally pubescent. *Illustrative Genera*:—Cichorium, *Linn.*; Taraxacum, *Haller.*

Of these sub-orders the Ligulifloræ is the best defined.

By Bentham and Hooker the Compositæ are divided into thirteen tribes.

Distribution and Numbers.—Universally distributed; but the Tubuliftoræ are most abundant in hot climates, and the Liguliftoræ in cold. The Labiatiftoræ are almost entirely confined to the extra-tropical regions of South America. In the northern parts of the world the plants of this order are universally herbaceous; but in South America, and some other parts of the southern hemisphere, they occasionally become shrubby, or even in some cases arborescent. Lindley calculated the order to contain about 9,000 species; but Bentham and Hooker have reduced it to about 1,000 genera and 8,000 species.

Properties and Uses.—The properties of the Compositæ are very variable. A bitter principle pervades the greater number of the species in a more or less evident degree, by which they are rendered tonic. Some are laxative and anthelmintic. Many contain a volatile oil, which communicates aromatic, carminative, and diaphoretic properties. Others are acrid stimulants, and the Liguliftoræ commonly abound in a bitter-tasting milky juice, which is sometimes narcotic.

Cohort 3.—*Campanales.*

Order 169. STYLIDIACEÆ, the Stylewort Order.—Character *Herbs* or *undershrubs*, not milky. *Leaves* exstipulate. *Calyx* superior, with from 2 to 6 divisions, persistent. *Corolla* with from 5 to 6 divisions; *æstivation* imbricate. *Stamens* 2, gynandrous. *Ovary* 2-celled, or rarely 1-celled; *style* forming a column with the filaments; *stigma* without an indusium. *Fruit* capsular. *Seeds* albuminous.

Distribution and Numbers.—They are chiefly found in the swamps of Australia. *Illustrative Genera:*—Stylidium, *Swartz*; Forstera, *Linn. fil.* There are about 120 species.

Properties and Uses.—Unknown.

Order 170. GOODENIACEÆ, the Goodenia Order.—Character.—*Herbs*, or rarely *shrubs*, not milky. *Leaves* exstipulate. *Flowers* never collected into heads. *Calyx* generally superior, with from 3 to 5 divisions, occasionally inferior. *Corolla* irregular, 5-parted; *æstivation* induplicate. *Stamens* 5; *filaments* distinct; *anthers* distinct or united. *Ovary* 1, 2, or rarely 4-celled; *placenta* free central; *style* 1; *stigma* surrounded by a hairy ring or somewhat cup-shaped expansion of the upper

part of the style termed an *indusium*. *Fruit* capsular, drupaceous, or nut-like. *Seeds* with fleshy albumen.

Distribution and Numbers.—These plants are principally natives of Australia and the islands of the Southern Ocean; rarely of India, Africa, and South America. *Illustrative Genera:*—Goodenia, *Sm.*; Leschenaultia, *R. Br.* There are about 200 species.

Properties and Uses.—Unimportant. Many are cultivated for the beauty of their flowers.

Order 171. CAMPANULACEÆ, the Harebell Order.—Character. *Herbaceous plants* or *undershrubs*, with a milky juice. *Leaves* nearly always alternate, exstipulate. *Flowers* scattered, or rarely in capitula. *Calyx* superior, persistent. *Corolla* gamo-

FIG. 1136.

FIG. 1137.

FIG. 1138.

Fig. 1136. Diagram of the flower of Rampions (*Campanula Rapunculus*).——*Fig.* 1137. Vertical section of the seed.——*Fig.* 1138. Vertical section of the flower.

petalous, regular, marcescent; *æstivation* valvate. *Stamens* equal in number to, and alternate with, the lobes of the corolla; *anthers* 2-celled, distinct or partly united. *Ovary* inferior, 2- or more-celled; *style* undivided, hairy; *stigma* naked. *Fruit* dry, capsular, dehiscing by lateral orifices or by valves at the apex; *placentas* axile. *Seeds* numerous, with fleshy albumen.

Distribution and Numbers.—Chiefly natives of the temperate parts of the northern hemisphere; a good many are, however, found in the southern hemisphere, especially at the Cape of Good Hope. A few species only are tropical. *Illustrative Genera:*—Phyteuma, *Linn.*; Campanula, *Linn.* There are about 550 species.

Properties and Uses.—The order does not contain any plants of particular importance from either a medicinal or an economic point of view.

Order 172. LOBELIACEÆ, the Lobelia Order.—Character.—

Herbs or *shrubs* with a milky juice. *Leaves* alternate, exstipulate. *Calyx* superior. *Corolla* gamopetalous, irregular, valvate. *Stamens* 5; *anthers* syngenesious. *Ovary* inferior, 1—3-celled; *placentas* axile or parietal; *style* 1; *stigma* surrounded by a fringe of hairs (*fig.* 1139). *Fruit* capsular, dehiscing at the apex. *Seeds* numerous, albuminous. *This order is especially distinguished from the Campanulaceæ by its irregular corollas and syngenesious anthers. It is made a tribe of the Campanulaceæ by Bentham and Hooker.*

Distribution and Numbers.—They are chiefly natives of tropical and sub-tropical regions; but a few occur in temperate and cold climates. *Illustrative Genera:* — Clintonia, *Doug.*; Lobelia, *Linn.* There are about 400 species.

FIG. 1140.

FIG. 1139.

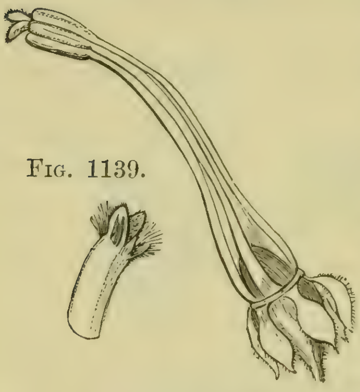


Fig. 1139. Stigma of *Lobelia syphilitica.* —*Fig.* 1140. The sporophylls of the above, with the calyx.

Properties and Uses.—The milky juice with which these plants abound is commonly of a very acrid nature; hence the species of this order should be regarded with suspicion. Indeed, some, as *Lobelia inflata*, *Tupa Feuillæi*, &c., act as narcotico-acrid poisons; and that of *Isotoma longiflora* is vesicant, and when taken internally it causes such violent purgation as to result in death.

Series 2.—*Superæ, or Heteromeræ.*

Cohort 1.—*Ericales.*

Order 173. VACCINIACEÆ, the Cranberry Order.—Character.—*Shrubs* or small *trees*. *Leaves* alternate, undivided, exstipulate.—*Calyx* superior. *Corolla* 4—6-lobed; *æstivation* imbricate. *Stamens* distinct, epigynous, twice as many as the lobes of the corolla; *anthers* appendiculate, with porous dehiscence. *Ovary* 4—10-celled; *style* and *stigma* simple. *Fruit* succulent. *Seeds* with fleshy albumen.

Distribution and Numbers.—Chiefly natives of the temperate regions of the globe. *Illustrative Genera:*—Vaccinium, Thibaudia. There are about 200 species.

Properties and Uses.—They are chiefly remarkable for

their astringent leaves and bark, and for their edible sub-acid fruits.

Order 174. ERICACEÆ, the Heath Order.—Character.—*Shrubs* or small *trees*. *Leaves* entire, evergreen, opposite, whorled or alternate, exstipulate. *Calyx* 4—5-cleft, inferior, persistent. *Corolla* hypogynous, gamopetalous, 4—5-cleft, or rarely distinct; *æstivation* imbricate. *Stamens* hypogynous, as many, or twice as many, as the divisions of the corolla; *anthers* 2-celled, opening by pores or slits, appendiculate. *Ovary* 4—5-celled, with numerous ovules, surrounded by a disc or scales; *placentas* axile; *style* 1; *stigma* simple or lobed. *Fruit* capsular or rarely baccate. *Seeds* numerous, small, anatropous; *embryo* minute in the axis of fleshy albumen.

Diagnosis.—Shrubs or small trees. Leaves entire, evergreen, exstipulate. Calyx and corolla 4—5-merous. Calyx inferior. Corolla hypogynous, gamopetalous, or rarely polypetalous. Stamens hypogynous; anthers 2-celled, appendiculate, dehiscing by pores or slits. Ovary 4—5-celled; style 1; placentas axile. Fruit capsular, or very rarely baccate. Seeds small, anatropous, numerous, with fleshy albumen.

Division of the Order and Illustrative Genera.—The order may be divided into five tribes as follows:—

FIG. 1141. FIG. 1142.

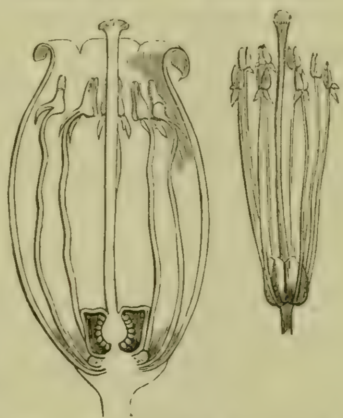


Fig. 1141. Vertical section of the flower of a species of Heath (*Erica*). ——*Fig.* 1142. Sporophylls of the same. The stamens are seen to be hypogynous.

Tribe 1. *Arbuteæ.*—Corolla deciduous. Fruit baccate. *Illustrative Genus:*—Arbutus, *Linn.*

Tribe 2. *Andromedeæ.*—Buds usually clothed with scales. Corolla deciduous. Fruit capsular, loculicidal. *Illustrative Genus:*—Andromeda, *Linn.*

Tribe 3. *Ericeæ.*—Buds naked. Corolla persistent. Fruit capsular, usually loculicidal, or rarely septicidal. *Illustrative Genera:*—Erica, *Linn.*; Calluna, *Salisb.*

Tribe 4. *Rhodoreæ.*—Buds scaly, cone-like. Corolla deciduous. Fruit capsular, septicidal. *Illustrative Genera:*—Azalea, *Linn.*; Phyllodoce, *Salisb.*

Tribe 5. *Pyroleæ.*—Herbs or somewhat shrubby plants. Corolla polypetalous, or the petals united at the base, deciduous. Fruit capsular, loculicidal. *Illustrative Genera:*—Pyrola, *Tourn.*; Chimaphila, *Pursh.*

Distribution and Numbers.—They are very abundant at the Cape of Good Hope, and are also more or less generally distributed in Europe, North and South America, and Asia. There are more than 900 species.

Properties and Uses.—The plants of this order are chiefly remarkable for astringent properties; some are tonic and diuretic, and others are narcotic, or even poisonous. This is especially the case with *Kalmia latifolia*, *Rhododendron chrysanthum*, *Andromeda floribunda*, and *Azalea pontica*. The fruits of many are edible.

Order 175. MONOTROPACEÆ, the Fir-rape Order.—Character.—*Saprophytes* with scale-like leaves. *Sepals* more or less distinct, 4—5, inferior. *Petals* 4—5, distinct or united. *Stamens* twice as many as the petals, hypogynous; *anthers* 2-celled, with longitudinal dehiscence. *Ovary* superior, 4—5-celled at the base, 1-celled with 5 parietal placentas at the apex. *Fruit* capsular, with loculicidal dehiscence. *Seeds* numerous, with a loose testa; *embryo* minute, at the apex of fleshy albumen. *This order is referred to Ericaceæ by Bentham and Hooker. It is closely allied to the Pyroleæ.*

Distribution and Numbers.—They are found growing on Firs chiefly, in the cool parts of Europe, Asia, and North America. *Illustrative Genus:*—Monotropa, *Nutt.* There are about 10 species.

Properties and Uses.—Unimportant.

Order 176. EPACRIDACEÆ, the Epacris Order.—Character. *Shrubs*, or small *trees*. *Leaves* alternate or rarely opposite, simple, with parallel or radiating veins. *Calyx* and *corolla* inferior, usually 5-partite, or rarely 4-partite. *Stamens* equal in number to the divisions of the corolla, or rarely fewer, hypogynous or adherent to the corolla; *anthers* 1-celled, without appendages, opening longitudinally. *Ovary* superior, many- or 1-celled; *style* simple. *Fruit* fleshy or capsular. *Seeds* with a firm skin, albuminous.

Distribution and Numbers.—Natives of Australia, the Indian Archipelago, and the South Sea Islands, where they are very abundant. *Illustrative Genera:*—Astroloma, *R. Br.*; Epacris, *Smith.* There are about 350 species.

Properties and Uses.—Of little importance, except for the beauty of their flowers, on which account they are much culti-

vated. The fruits of many species are edible, as those of *Astroloma humifusum*, the Tasmanian Cranberry; *Leucopogon Richei*, the Native Currant of Australia; *Lissanthe sapida*, and others.

Orders 177 and 178. DIAPENSIACEÆ and STILBACEÆ.—These are two small orders of shrubby plants, which are placed by Lindley in his Gentianal alliance, and regarded by him as nearly allied to Loganiaceæ. The Diapensiaceæ are better regarded, however, as being near to the Ericaceæ; some botanists refer them to Convolvulaceæ. They have also affinities with both Polemoniaceæ and Hydrophyllaceæ. They are but 2 genera and 2 species, the uses of which are unknown. They are natives of North America and Northern Europe.—The Stilbaceæ, of which there are 3 genera and 7 species, without any known uses, are natives of the Cape of Good Hope.

FIG. 1143.

FIG. 1144.

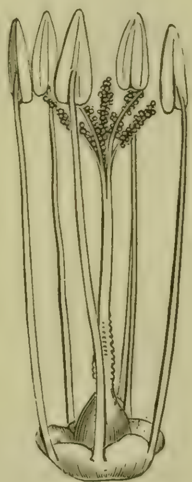


Fig. 1143. Diagram of the flower of a species of *Plumbago*.——*Fig.* 1144. Sporophylls of the same.

Cohort II.—*Primulales.*

Order 179. PLUMBAGINACEÆ, the Thrift Order.—Character. *Herbs* or *undershrubs*. *Leaves* entire, alternate or radical, exstipulate. *Flowers* regular. *Calyx* tubular, plaited, persistent, 5-partite. *Corolla* membranous, 5-partite or of 5 petals, or rarely absent. *Stamens* 5, opposite the petals, to which they are attached when the corolla is polypetalous and hypogynous, and opposite to the divisions of the corolla when this is gamopetalous. *Ovary* 1-celled; *ovule* solitary, suspended from a long funiculus arising from the base of the cell; *styles* usually 5, some-

times 3 or 4. *Fruit* utricular, or dehiscing by valves at the apex. *Seed* solitary; *embryo* straight; *albumen* mealy, and small in quantity.

Distribution and Numbers.—Chiefly found growing on the seashore and in salt marshes in various parts of the globe, but by far the greater number inhabit temperate regions. *Illustrative Genera:*—Armeria, *Willd.*; Plumbago, *Tourn.* There are about 250 species.

Properties and Uses.—Of little importance, but acridity and astringency appear to be the most remarkable properties of the plants of this order.

Order 180. PRIMULACEÆ, the Primrose Order.—Character. *Herbs. Leaves* cauline, and then simple, opposite, whorled, or

FIG. 1145.

FIG. 1146.

FIG. 1147.

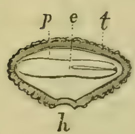


Fig. 1145. Flower of the Pimpernel (*Anagallis arvensis*). *c.* Calyx. *p.* Petals. *s.* Stamens.——*Fig.* 1146. Vertical section of the flower of the same. *pl.* Free central placenta. *s.* Style and capitate stigma.——*Fig.* 1147. Vertical section of the seed of *Primula elatior*. *t.* Integuments. *p.* Albumen. *e.* Embryo. *h.* Hilum.

rarely alternate, exstipulate; or radical. *Flowers* regular, perfect. *Calyx* generally 4-cleft, or rarely 4—5-cleft, persistent, inferior, or semi-superior in *Samolus*. *Corolla* usually 5- or rarely 4—9-cleft, very rarely absent, or rarely of distinct petals. *Stamens* equal in number to the segments of the corolla or separate petals, and opposite to them, or in apetalous flowers hypogynous and alternating with the divisions of the calyx. *Ovary* superior, or rarely partly inferior, 1-celled; *placenta* free central; *style* 1; *stigma* capitate. *Fruit* a capsule, dehiscing transversely, and forming a pyxis, or opening by valves. *Seeds* numerous, with fleshy or horny albumen; *embryo* placed transversely to the hilum.

Diagnosis.—Herbs with simple, exstipulate, cauline or radical

leaves, and regular perfect flowers. Stamens equal in number to the lobes of the corolla or separate petals and opposite to them. Ovary superior, 1-celled, with a free central placenta; style 1; stigma capitate. Fruit capsular, with transverse or longitudinal dehiscence. Seeds numerous, with albumen, and the embryo parallel to the hilum.

Distribution and Numbers.—These plants principally inhabit cold and temperate regions in the northern parts of the lobe. They are rare in the tropics, where they are found only on the seashore or in mountainous districts. *Illustrative Genera:*—Primula, *Linn.*; Anagallis, *Tourn.*; Glaux, *Tourn.*; Samolus, *Tourn.* There are about 250 species.

Properties and Uses.—Of no particular importance except for the beauty of their flowers. The flowers of the Cowslip (*Primula veris*) are sedative and diaphoretic, and are sometimes employed in the manufacture of a soporific wine. The roots of Cyclamens are acrid, especially those of *Cyclamen hederæfolium*, which have been used as a drastic purgative and emmenagogue.

Order 181. MYRSINACEÆ, the Myrsine Order.—Character.—*Trees* or *shrubby plants*. *Leaves* coriaceous, smooth, exstipulate. *Flowers* small, perfect or unisexual. *Calyx* and *corolla* 4—5-partite. *Stamens* usually corresponding in number to the divisions of the corolla and opposite to them, but sometimes there are also 5 sterile petaloid alternate ones; *anthers* dehiscing longitudinally. *Ovary* superior or nearly so, 1-celled; with a free central *placenta*, in which the ovules are imbedded. *Fruit* fleshy. *Seeds* 1, 2, or many; *albumen* abundant, horny.

Distribution and Numbers.—Chiefly natives of the islands of the southern hemisphere. *Illustrative Genera:*—Myrsine, *Linn.*; Theophrasta, *Linn.* There are more than 300 species.

Properties and Uses.—Of little importance. The fruits and seeds of some species are pungent, and the seeds of others are said to be purgative.

Cohort 3.—*Ebenales.*

Order 182. SAPOTACEÆ, the Sapota Order.—Character.—*Trees* or *shrubs*, often having a milky juice. *Leaves* alternate, simple, entire, coriaceous, exstipulate. *Flowers* small, hermaphrodite. *Calyx* inferior, usually with 5, or sometimes with 4—8 divisions, persistent. *Corolla* with as many divisions as the calyx, or twice or thrice as many. *Stamens* definite, in a single row, half of them sterile and alternating with the fertile ones, the latter being opposite to the segments of the corolla;

anthers commonly extrorse. *Ovary* 4—12-celled, with a solitary anatropous ovule in each cell ; *style* 1. *Fruit* fleshy. *Seeds* large, with a shining bony testa ; *embryo* large, usually in albumen, and with a short radicle.

Distribution and Numbers.—Natives chiefly of the tropical parts of Asia, Africa, and America. *Illustrative Genera* :—Chrysophyllum, *Linn.* ; Isonandra, *Wight* ; Bassia, *König*. There are about 220 species.

Properties and Uses.—Many species yield edible fruits; others are valuable timber trees. The seeds of several contain a fatty oil. Some have bitter astringent febrifugal barks, and the milky juices of others yield a substance resembling in its general characters caoutchouc or india-rubber.

Order 183. EBENACEÆ, the Ebony Order.—Character.—*Trees* or *shrubs* without milky juice. *Leaves* alternate, entire, coriaceous, exstipulate. *Flowers* polygamous. *Calyx* 3—7-partite, inferior, persistent. *Corolla* 3—7-partite. *Stamens* equal in number to the lobes of the corolla, or twice or four times as many, epipetalous or hypogynous ; *anthers* 2-celled, introrse, opening longitudinally. *Ovary* 3—12-celled, each cell with 1 or 2 ovules suspended from the apex ; *style* usually having as many divisions as there are cells to the ovary. *Fruit* fleshy. *Seeds* large, albuminous ; *radicle* superior.

Distribution and Numbers.—They are mostly natives of tropical India, but a few occur in colder regions. *Illustrative Genera* :—Royena, *Linn.* ; Diospyros, *Linn.* There are nearly 200 species.

Properties and Uses.—Many of the trees of this order are remarkable for the hardness of their wood, which is commonly known under the names of Ebony and Ironwood. Many species have edible fruits, and some have astringent barks.

Order 184. STYRACEÆ, the Storax Order.—Character.—*Trees* or *shrubs*. *Leaves* simple, alternate, exstipulate. *Flowers* axillary, hermaphrodite. *Calyx* inferior or partially superior, 4—5-partite or almost entire, persistent. *Corolla* of from 5 to 10 petals, either united at the base or distinct ; *æstivation* imbricate or somewhat valvate. *Stamens* equal in number to the petals, or twice or thrice as many, more or less united at the base ; *anthers* 2-celled, roundish or linear. *Ovary* superior or partially inferior ; *style* simple. *Fruit* drupaceous, always more or less fleshy. *Seeds* usually 1 in each cell, sometimes more ; *embryo* in the midst of abundant fleshy albumen, with a long radicle.

Miers divides the *Styraceæ* into two orders, called *Symplocaceæ* and *Styracaceæ*, the former of which is distinguished by its partially inferior ovary, imbricate æstivation of corolla, and roundish anthers; and the latter having a superior ovary, valvate æstivation of corolla, and linear anthers.

Distribution and Numbers.—These plants are sparingly distributed in warm and tropical regions; but a few are found in cold climates. *Illustrative Genera*:—Symplocos, *Jacq.*; Styrax, *Tourn.* Miers enumerates about 120 species.

Properties and Uses.—These plants are principally remarkable for yielding stimulant balsamic resins. Some yield dyeing agents, but these are of little importance.

Series 3.—*Dicarpiæ or Bicarpellatæ.*

Cohort 1.—*Gentianales.*

Order 185. OLEACEÆ, the Olive Order.—Character.—*Trees* or *shrubs*. *Leaves* opposite, simple or pinnate, exstipulate.

FIG. 1148. FIG. 1149. FIG. 1150.

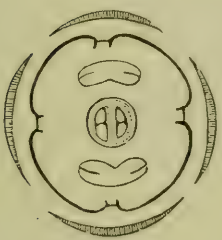


Fig. 1148. Diagram of the flower of the Lilac (*Syringa vulgaris*).——*Fig.* 1149. Flower of the Manna Ash (*Fraxinus Ornus*), with 4-cleft calyx; corolla with 4 distinct petals; 2 stamens; and 2 carpels.——*Fig.* 1150. Vertical section of the calyx and pistil of the Privet (*Ligustrum vulgare*).

Flowers usually perfect, or rarely unisexual. *Calyx* persistent, 4—8-cleft, sometimes obsolete, inferior. *Corolla* regular, 4—8-cleft, or of 4 distinct petals, or absent; *æstivation* valvate or imbricate. *Stamens* usually 2, rarely 4. *Ovary* superior, 2-celled, with 1—4 erect, or 2 suspended ovules in each cell. *Fruit* dehiscent or indehiscent, often 1-seeded. *Seeds* with abundant fleshy albumen, or the albumen is small in quantity; *embryo* straight.

The order Jasminaceæ of many botanists is here included in the Oleaceæ. The tribe or sub-order Jasmineæ is more

especially distinguished from other Oleaceæ by the imbricate æstivation of the corolla, erect ovules, and the small quantity of albumen in the seed.

Distribution and Numbers.—The plants of this order are principally natives of temperate and warm regions, but some also occur within the tropics. *Illustrative Genera:*—Olea, *Linn.*; Ligustrum, *Tourn.*; Fraxinus, *Tourn.*; Jasminum, *Linn.* There are about 250 species.

Properties and Uses.—The barks of many plants of this order are tonic and febrifugal. The mild purgative called Manna is obtained from a species of Ash. The pericarp of the common Olive yields the well-known Olive Oil. Other species are remarkable for the hardness of their wood. The plants of the Jasmineæ have generally fragrant flowers. The volatile oil of Jasmine, which is used in perfumery, is chiefly obtained by distillation from the flowers of *Jasminum officinale* and *J. grandiflorum*. The fragrant flowers of *J. Sambac* are used as votive offerings in India; they are also said to have much power in arresting the secretion of milk. The leaves and roots of some species of *Jasminum* are reputed bitter, and have been employed for various purposes, but generally speaking this tribe contains no active medicinal plants. The flowers of *Nyctanthes Arbor tristis* are employed in India for dyeing yellow.

Order 186. SALVADORACEÆ, the Salvadora Order.—Character.—*Shrubs* or small *trees*. *Leaves* opposite, entire, leathery, exstipulate. *Flowers* small, panicled. *Calyx* of 4 sepals. *Corolla* 4-partite, membranous. *Stamens* 4. *Ovary* 1—2-celled; *stigma* sessile. *Fruit* fleshy, 1-celled, with a solitary erect seed. *Seeds* exalbuminous.

Distribution and Numbers.—Natives of India, Syria, and North Africa. *Illustrative Genera:*—Salvadora, *Linn.*; Monetia, *L'Hérit.*

Properties and Uses.—Some are acrid and stimulant. The fruit of *Salvadora persica* is edible, and resembles the garden Cress in taste. The bark of the root is acrid, and is employed as a blistering agent in India. The leaves are reputed to be purgative.

Order 187. APOCYNACEÆ, the Dogbane Order.—Character.—*Trees* or *shrubs*, juice usually milky and acrid. *Leaves* entire, commonly opposite, but occasionally whorled or scattered, exstipulate. *Calyx* inferior, 5-partite, persistent. *Corolla* 5-lobed; *æstivation* contorted. *Stamens* 5, alternate with the lobes of the corolla; *filaments* distinct; *anthers* united to the

stigma, 2-celled; *pollen* granular. *Ovary* composed of 2 carpels, which are generally merely in contact, but sometimes united so as to form a 2-celled or more rarely a 1-celled ovary; *styles* 2 or 1; *stigma* 1, expanded at the base and apex, and contracted in the middle, so as to resemble in form an hour-glass or dumb-bell; *ovules* numerous. *Fruit* consisting of 1 or 2 follicles, or a capsule, drupe, or berry. *Seeds* usually with albumen, or rarely exalbuminous, often comose.

Distribution and Numbers.—Natives principally of the tropics, but a few occur in northern regions. *Vinca* is the only British genus. *Illustrative Genera*:—Allamanda, *Linn.*; Urceola, *Roxb.*; Apocynum, *Tourn.* There are about 600 species.

Properties and Uses.—The plants of this order are generally

FIG. 1151.

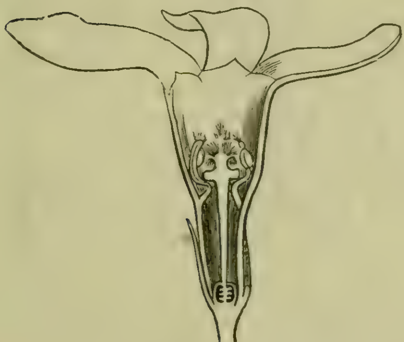


FIG. 1152.

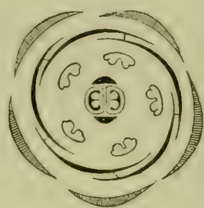


Fig. 1151. Vertical section of the flower of Periwinkle (*Vinca*). ——*Fig.* 1152. Diagram of the flower of the same.

to be suspected, as many of them are intensely poisonous, although the fruits of a few species are edible. Some are drastic purgatives, and of others the bark is tonic and febrifugal. India-rubber or Caoutchouc, now commonly known in commerce as Rubber, is obtained from the milky juice of several species.

Order 188. ASCLEPIADACEÆ, the Asclepias Order.—Character.—*Shrubs* or *herbs*, commonly milky, frequently twining and sometimes succulent. *Leaves* entire, opposite or whorled, or rarely scattered, exstipulate. *Flowers* regular. *Calyx* and *corolla* 5-partite; *æstivation* of the latter imbricate or rarely valvate; the calyx persistent, the corolla deciduous. *Stamens* 5, alternate with the lobes of the corolla; *filaments* usually combined so as to form a tube round the pistil, or sometimes distinct; *anthers* frequently having pouch-shaped and hornlike

appendages (*fig.* 1156, *p*), the pollen of each anther-lobe forming a pollinium; the right-hand pollinium of each anther united to the left-hand one of the contiguous anther by a gummy process formed by the stigma (*fig.* 1153, *b*). *Ovary* superior, of 2 carpels, which are more or less adherent below, but distinct above; *styles* 2; *stigmas* united and expanded into a fleshy 5-cornered head, the processes joining the pollinia arising from its angles. *Fruit* consisting of 2 follicles, or 1 by abortion. *Seeds* numerous, generally comose, with thin albumen.

Diagnosis.—This order is distinguished amongst the Dicarpiæ by its curiously formed stigma and adhering pollinia.

Distribution and Numbers.—They are chiefly tropical plants,

FIG. 1153.

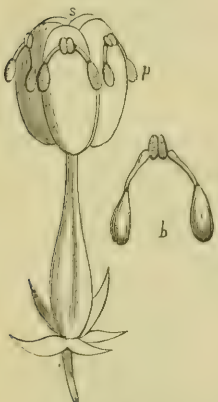


FIG. 1154.

FIG. 1155.

FIG. 1156.

Fig. 1153. Pistil of a species of *Asclepias*, with the pollinia, *p*, adhering to the stigma, *s*. *b*. Pollen-masses as detached from contiguous anthers.——*Fig.* 1154. Diagram of the flower of *Asclepias nivea*.——*Fig.* 1155. Flower of a species of *Asclepias*, with the stamens united and forming a tube round the pistil. *p*. Corolla. *a*. Appendages of the stamens.——*Fig.* 1156. One of the stamens of the same removed. *f*. Filament. *a*. Anther. *p*. Hornlike appendage of the filament.

abounding in southern Africa, India, and equinoctial America. A few occur in Southern Europe. *Illustrative Genera:*—Hemidesmus, *R. Br.*; Asclepias, *Linn.*; Hoya, *R. Br.*; Stapelia, *Linn.* There are about 1,000 species.

Properties and Uses.—The plants of this order are chiefly remarkable for their bitter acrid juice, which renders them stimulant, emetic, purgative, and diaphoretic. Several species are reputed to be antidotes to snake-bites. Some species yield Caoutchouc; but no important commercial kind of Rubber is obtained from them. Parts of some are edible, as the roots of *Gomphocarpus pedunculatus*, and the tubers of *Ceropegia Vignaldiana*, &c.

Order 189. LOGANIACEÆ, the Strychnos Order.—Character. *Shrubs*, *herbs*, or *trees*. *Leaves* opposite, entire, stipulate; the stipules, however, sometimes exist only in the form of a raised line or ridge. *Calyx* inferior, 4—5-partite. *Corolla* regular, 4—5- or 10-cleft; *æstivation* valvate, contorted, or imbricate. *Stamens* epipetalous, usually equal in number, but sometimes unequal, to the lobes of the corolla; *anthers* 2-celled. *Ovary* 2- 3- or 4-celled; *style* simple below, and with as many divisions above as there are cells to the ovary; *stigma* simple. *Fruit* capsular or drupaceous; *placentas* axile, ultimately detached. *Seeds* usually peltate, sometimes winged, with fleshy or cartilaginous albumen. *This order is by no means well defined.*

Distribution and Numbers.—Nearly all natives of tropical regions. *Illustrative Genera*:—Spigelia, *Linn.*; Strychnos, *Linn.* There are about 200 species.

Properties and Uses.—These plants are almost universally poisonous, acting on the nervous system and producing frightful convulsions. Several have been used in medicine in torpid or paralytic conditions of the muscular system, and for their valuable tonic, anthelmintic, and other properties; but they require much caution in their employment, and can generally be only given in very small doses.

Order 190. GENTIANACEÆ, the Gentian Order.—Character.—*Herbs*, or rarely *shrubs*, usually smooth. *Leaves* generally simple, entire, opposite, sessile, and strongly ribbed; rarely alternate, or stalked, or compound; always exstipulate. *Flowers* regular, solitary and terminal, or in di—tri-chotomous cymes. *Calyx* inferior, persistent, usually with 5 divisions, or occasionally with 4, 6, 8, or 10. *Corolla* marcescent, its divisions corresponding in number to those of the calyx; *æstivation* imbricate-twisted or induplicate. *Stamens* as many as the segments of the corolla and alternate with them. *Ovary* 1-celled, or rarely partially 2-celled from the projection inwards of the placentas; *ovules* numerous; *placentas* 2, parietal, anterior and posterior to the axis, and frequently turned inwards; *style* 1; *stigmas* 2, right and left of the axis. *Fruit* capsular, 1—2-celled, 2-valved, with septicidal dehiscence; or rarely fleshy and indehiscent. *Seeds* numerous, small; *embryo* minute, in the axis of fleshy albumen.

Diagnosis.—Usually smooth herbs. Leaves exstipulate. Inflorescence definite. Flowers regular, solitary and terminal, or in cymes. Calyx and corolla persistent, with an equal number of lobes. Stamens alternate to the lobes of the corolla, and

equal to them in number. Ovary superior, 1-celled, with 2 anterior and posterior parietal placentas, very rarely meeting in the centre and forming a 2-celled ovary; style 1; stigmas 2. Seeds small, numerous, with a minute embryo in the axis of fleshy albumen.

Division of the Order and Illustrative Genera.—The order may be divided into two sub-orders as follows:—

Sub-order 1. GENTIANEÆ.—Leaves opposite, corolla imbricate-twisted. *Illustrative Genera:*—Gentiana, *Linn.*; Chlora, *Linn.*

Sub-order 2. MENYANTHEÆ.—Leaves alternate, corolla induplicate. *Illustr. Genera:*—Menyanthes, *Tourn.*; Villarsia, *Vent.*

Distribution and Numbers.—They are found in nearly all parts of the world, inhabiting both the coldest and the hottest regions. There are upwards of 500 species.

Properties and Uses.—A bitter principle almost universally pervades the plants of this order; hence many of them are tonic, stomachic, and febrifugal.

Cohort 2.—*Polemoniales.*

Order 191. POLEMONIACEÆ, the Phlox Order.—Character.—*Herbs. Leaves* opposite or alternate, simple or compound, exstipulate. *Calyx* inferior, 5-partite, persistent, generally regular. *Corolla* 5-lobed with contorted or occasionally imbricate æstivation. *Stamens* 5, alternate with the segments of the corolla; *pollen* usually of a blue colour. *Ovary* 3-celled; *style* 1; *stigma* trifid. *Fruit* capsular, 3-celled, 3-valved; *placentas* axile. *Seeds* few or many; *embryo* straight, in the axis of copious horny albumen; *cotyledons* elliptical, foliaceous.

Distribution and Numbers.—They abound most in the temperate parts of North and South America; but are far less abundant in Europe and Asia, and altogether unknown in tropical countries. *Illustrative Genera:*—Phlox, *Linn.*; Polemonium, *Tourn.*; Cobæa, *Cav.* There are more than 100 species.

Properties and Uses.—Of no importance.

Order 192. HYDROPHYLLACEÆ, the Hydrophyllum Order.—Character.—*Herbs, bushes,* or small *trees. Leaves* usually alternate, hairy, and lobed. *Flowers* either solitary, stalked, and axillary; or numerous and arranged in a helicoid cyme. *Calyx* persistent, 5-partite. *Corolla* regular, 5-cleft. *Stamens* equal in number to, and alternate with, the segments of the

corolla. *Ovary* 1—2-celled, with two parietal placentas ; *styles* and *stigmas* 2 ; *ovules* 2 or many. *Fruit* capsular, 2-valved, 2- or 1-celled. *Seeds* netted ; *albumen* hard, abundant.

Distribution and Numbers.—Chiefly natives of the northern and most southern parts of the American continent. *Illustrative Genera :*—Hydrophyllum, *Tourn.* ; Nemophila, *Bart.* There are about 80 species.

Properties and Uses.—Unimportant.

Order 193. BORAGINACEÆ, the Borage Order.—Character.—*Herbs* or rarely *shrubs*, with more or less rounded, usually rough and hairy stems. *Leaves* alternate, entire, or rarely sinuated, usually rough, exstipulate. *Inflorescence* a helicoid cyme or a unilateral raceme. *Flowers* regular, symmetrical. *Calyx* persistent, inferior, 4—5-partite, or -lobed. *Corolla* regular or nearly so, 4—5-partite, usually with scales in its throat ; *æstivation* imbricate. *Stamens* equal in number to the lobes of the corolla and alternate with them. *Ovary* superior, and composed of two carpels, each of which is 2-lobed and 2-celled, with a solitary pendulous ovule in each cell ; *style* 1, basilar ; *stigma* simple or bifid. *Fruit* consisting of from 2 to 4 distinct achænia, placed at the bottom of the persistent calyx. *Seeds* exalbuminous ; *embryo* straight, with a superior radicle.

FIG. 1157.

FIG. 1158.

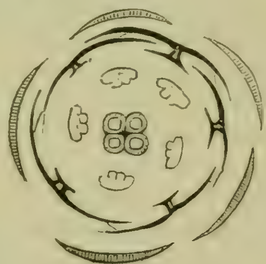


Fig. 1157. Vertical section of the fruit of a species of *Myosotis*. Two achænia are seen, and two have been removed.——*Fig.* 1158. Diagram of the flower of the Comfrey (*Symphytum officinale*).

Diagnosis.—Herbs with rounded, usually rough stems, and alternate exstipulate leaves. Inflorescence helicoid or unilateral. Flowers regular and perfect. Sepals, petals, and stamens equal in number, the latter being alternate with the divisions of the corolla. Ovary superior, deeply 4-lobed, with one ovule in each lobe ; style 1, basilar. Fruit composed of 2—4 achænia placed at the bottom of the persistent calyx. Seeds exalbuminous.

Distribution and Numbers.—Chiefly natives of temperate regions in the northern hemisphere. *Illustrative Genera :*—

Echium. *Linn.*; Borago. *Tourn.*; Cynoglossum, *Linn.* There are nearly 700 species.

Properties and Uses.—The plants of this order are chiefly remarkable for their mucilaginous properties.

Order 194. EHRETIACEÆ, the Ehretia Order.—*Diagnosis.*—These plants resemble the Boraginaceæ in most of their characters, but they differ in having their carpels so completely united as to form a 2- or more-celled ovary; in their terminal style; and drupaceous fruit. They are usually characterised also by the presence of a small quantity of albumen in their seeds, but this is sometimes absent. *By Bentham and Hooker the Ehretiaceæ are made a sub-order of the Boraginaceæ.*

Distribution and Numbers.—Chiefly tropical plants. *Illustrative Genera*:—Ehretia, *Linn.*; Heliotropium, *Linn.* There are about 300 species.

Properties and Uses.—Unimportant.

Order 195. CORDIACEÆ, the Cordia Order.—Character.—*Trees* with alternate scabrous *leaves*, exstipulate. *Calyx* and *corolla* 5-merous; *æstivation* of the corolla imbricate-twisted. *Stamens* 5, alternate with the segments of the corolla; *anthers* versatile. *Ovary* superior, 4—8-celled, with 1 pendulous ovule in each cell: *stigma* 4—8-cleft. *Fruit* drupaceous, 4—8-celled; frequently some of the cells are abortive; *placentas* axile, *Seeds* 1 in each cell, pendulous by a long cord; *albumen* none; *cotyledons* plaited longitudinally. *This order is combined by Bentham and Hooker with Boraginaceæ.*

Distribution and Numbers.—Natives almost exclusively of tropical regions. *Illustrative Genera*:—Cordia, *Plum.*; Varronia, *DC.* There are more than 180 species.

Properties and Uses.—The fruits of many species are edible; the bark of *C. Myxa* is reputed to be a mild tonic and astringent; some species yield timber.

Order 196. CONVOLVULACEÆ, the Convolvulus Order.—Character.—*Herbs* or *shrubs*, generally twining or trailing, or sometimes erect; sometimes leafless and parasitic; juice frequently milky. *Leaves* or *scales* alternate, exstipulate. *Calyx* inferior, with deep divisions, much imbricate, persistent. *Corolla* 5-partite or 5-plaited, regular, deciduous, sometimes with scales in its tube; *æstivation* twisted, plaited or imbricate. *Stamens* 5, alternate with the lobes of the corolla. *Disc* annular, hypogynous. *Ovary* 2- 3- or 4-celled, or the carpels are more or less distinct; *styles* 1 or 2, usually 2-fid; *ovules* 1—2 in each cell or carpel, erect. *Fruit* capsular, 1—4-celled, with septifragal

dehiscence, or bursting tranversely at the base. *Embryo* large, curved or coiled in a small quantity of mucilaginous albumen, with foliaceous crumpled cotyledons ; in *Cuscuta* the embryo is filiform, spiral, and the cotyledons scarcely perceptible ; *radicle* inferior.

Diagnosis.—Generally twining or trailing milky herbs, with alternate exstipulate leaves ; or parasitic and leafless. Calyx

FIG. 1159.

FIG. 1160.

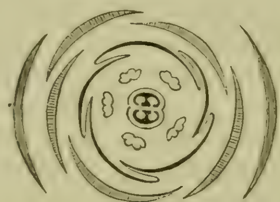


FIG. 1161.

FIG. 1162.

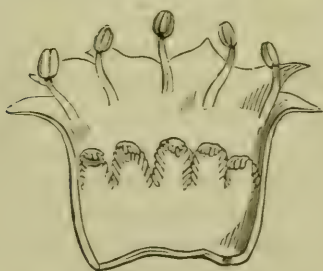


FIG. 1163.

Fig. 1159. Flower of Great Bindweed (*Convolvulus sepium*).——*Fig.* 1160. Diagram of the same flower, showing two bracts on the outside of the calyx. *Fig.* 1161. Vertical section of the seed of the same.——*Fig.* 1162. Corolla of Dodder (*Cuscuta*) laid open to show five epipetalous stamens and the scales in its tube.——*Fig.* 1163. Spiral embryo of a species of *Cuscuta*.

of 5 imbricate sepals, inferior. Corolla regular, 5-plaited or 5-lobed. Stamens 5, alternate with the lobes of the corolla. Ovary 2–4-celled. Fruits 2—4-celled, capsular, septifragal. Embryo curved, coiled, or spiral, in albumen ; radicle inferior.

Distribution and Numbers.—They are found chiefly in the plains and valleys of hot and tropical regions. A few occur in temperate climates, but they are altogether absent in the coldest

latitudes. *Illustrative Genera :*—Convolvulus, *Linn.*; Ipomœa, *Linn.*; Cuscuta, *Linn.* There are about 750 species.

Properties and Uses.—They are chiefly remarkable for the presence of an acrid milky purgative juice in their roots; hence the order includes some important medicinal plants. In the roots of some species this purgative principle is either absent or in but small quantity. The seeds also of some species are purgative. The Cuscuteæ are leafless parasites.

Order 197. Nolanaceæ, the Nolana Order.—Character.—*Herbs* or *shrubs*. *Leaves* alternate, exstipulate. *Calyx* 5-partite, persistent, with a valvate æstivation. *Corolla* regular, with a plaited æstivation. *Stamens* 5, opposite to the lobes of the calyx. *Ovary* composed of from 5 to 20 carpels, either distinct or more or less combined into several bundles; *style* on a fleshy disc, simple; *stigma* simple. *Fruit* composed of 5 or more separate or more or less combined achænia, which are enclosed in the persistent calyx. *Seed* with a little albumen; *embryo* curved; *radicle* inferior. *This order is combined by Bentham and Hooker with Convolvulaceæ; and by others it has been referred to Boraginaceæ.*

Distribution and Numbers.—Natives exclusively of South America, especially of Chili. *Illustrative Genera :*—Nolana, *Linn.*; Alona, *Lindl.* There are about 36 species.

Properties and Uses.—Unknown.

Order 198. Solanaceæ, the Solanum Order.—Character.—*Herbs*, or rarely *shrubs*, or *trees*, with a colourless juice. *Leaves* alternate, often in pairs. *Inflorescence* axillary, or frequently extra-axillary. *Flowers* isomerous. *Calyx* with 5 or rarely 4 divisions, usually persistent, often growing during the ripening of the fruit (*accrescent*). *Corolla* regular or somewhat irregular, 5- or rarely 4-partite; *æstivation* valvate, induplicate, plaited, or imbricate. *Stamens* equal in number to the lobes of the corolla, with which they are alternate; *anthers* 2-celled, sometimes connate above, with longitudinal or porous dehiscence. *Ovary* superior, usually 2-celled, rarely 3—5-celled; *style* undivided, *stigma* simple or 2-lobed. *Fruit* capsular or baccate, 2- or more-celled. *Seeds* numerous, albuminous; *embryo* straight, or usually curved in a more or less annular or spiral form.

Diagnosis.—Herbs or rarely shrubs or trees, with alternate leaves, and a colourless juice. Flowers isomerous. Calyx and corolla with 5, or rarely 4 divisions. Corolla regular or very slightly irregular; æstivation valvate, imbricate, plaited, or induplicate. Stamens equal in number to the lobes of the

corolla, with which they are alternate; anthers 2-celled, with porous or longitudinal dehiscence. Ovary superior, with axile placentation, usually 2-celled, or rarely more-celled. Fruit de-

FIG. 1164.

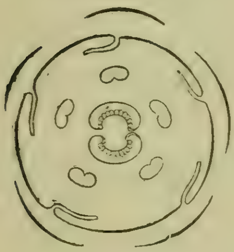


FIG. 1165.

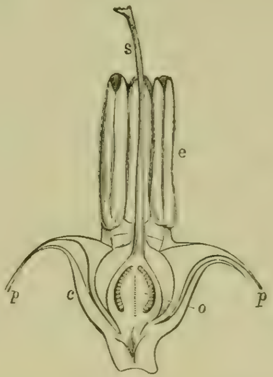


FIG. 1166.

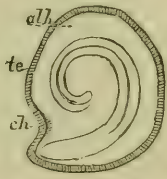


Fig. 1164. Diagram of the flower of the Potato (*Solanum tuberosum*).——*Fig.* 1165. Vertical section of the same. *c.* Calyx. *p, p.* Corolla. *o.* Ovary. *e.* Stamens. *s.* Style and stigma.——*Fig.* 1166. Vertical section of the seed of *Solanum Dulcamara*. *te.* Testa. *ch.* Chalaza. *alb.* Albumen, enclosing the curved embryo.

FIG. 1167.

FIG. 1168.

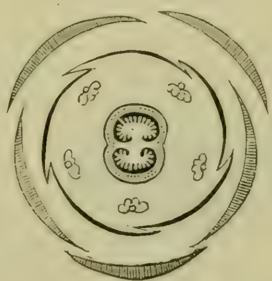


Fig. 1167. Vertical section of the flower of Tobacco (*Nicotiana Tabacum*).——*Fig.* 1168. Diagram of the flower of the same.

hiscent or indehiscent, 2- or more-celled. Seeds numerous, albuminous.

The Solanaceæ may be divided as follows:—

Sub-order 1. SOLANEÆ.—Æstivation of the corolla valvate or

induplicate. Stamens equal in number to the lobes of the corolla. *Illustrative Genera:*—Cestrum, *Linn.*; Solanum, *Linn.*

Sub-order 2. ATROPEÆ.—Æstivation of the corolla imbricate, or some modification of imbricate. Stamens equal in number to the lobes of the corolla, one occasionally sterile. *Illustrative Genera:*—Atropa, *Linn.*; Lycium, *Linn.*

Distribution and Numbers.—They are scattered over most parts of the globe except the polar circles, but are most abundant in tropical regions. This order, as defined above, contains about 1,120 species.

Properties and Uses.—The plants of this order frequently possess narcotic properties. Some are pungent and stimulant owing to the presence of an acrid oleo-resin; others contain a bitter tonic principle; and a few have edible fruits, leaves, or tubers.

Cohort 3.—*Personales.*

Order 199. SCROPHULARIACEÆ, the Figwort Order.—Character.—*Herbs*, or rarely *shrubby plants*, with alternate, opposite,

FIG. 1169.

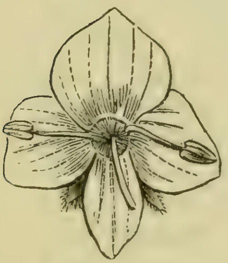


FIG. 1170.

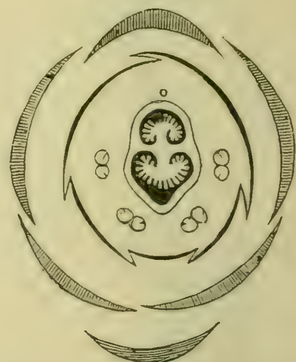


Fig. 1169. Flower of a species of Speedwell (*Veronica*).——*Fig.* 1170. Diagram of the flower of the Great Snapdragon (*Antirrhinum majus*), with one bract below.

or whorled *leaves*; generally without, or very rarely with, stipules; sometimes parasitic on roots. *Inflorescence* axillary. *Flowers* anisomerous, irregular. *Calyx* inferior, persistent, 4—5-partite. *Corolla* more or less irregular, sometimes gibbous or spurred, 4—5-partite; *æstivation* imbricate. Stamens gene-

rally 4, and didynamous, or sometimes 2, or rarely 5 or with a rudimentary fifth; *anthers* 1—2-celled. *Ovary* usually 2-celled with axile placentation; *style* 1; *stigma* undivided or 2-lobed. *Fruit* usually capsular, with variable dehiscence, or rarely baccate, usually 2-celled. *Seeds* generally numerous, small, albuminous; *embryo* straight or slightly curved.

Diagnosis.—Herbs, or rarely shrubs. Flowers irregular, anisomerous. Inflorescence axillary. Calyx and corolla with 4 or 5 divisions. Corolla more or less irregular, æstivation imbricate. Stamens 4, didynamous, or sometimes 2, or rarely 5, or with a rudimentary fifth or staminode; anthers 1—2-celled. Ovary usually 2-celled, with axile placentation; style 1. Fruit capsular, or rarely baccate. Seeds generally numerous, albuminous.

Distribution and Numbers.—The plants of this order are found in all parts of the globe. *Illustrative Genera*:—Scrophularia, *Linn.*; Antirrhinum, *Tourn.*; Verbascum, *Linn.*; Veronica, *Tourn.* As above defined, there are about 1,700 species.

Properties and Uses.—The plants of this order must be regarded with suspicion, as some are powerful poisons. Many are bitter, others astringent, some purgative, emetic, or diuretic, and a few possess narcotic properties. A great many species are cultivated in our gardens, &c., on account of the beauty of their flowers.

Order 200. OROBANCHACEÆ, the Broom-rape Order.—Character.—*Herbs* of a more or less fleshy character, growing parasitically on the roots of other plants. *Stems* with scalelike leaves. *Calyx* persistent, toothed. *Corolla* irregular, persistent; *æstivation* imbricate. *Stamens* 4, didynamous; *anthers* 1—2-celled. *Ovary* 1-celled; its 2 component carpels being placed right and left of the axis; *placentas* 2—4, parietal; *style* 1; *stigma* 2-lobed. *Fruit* a capsule. *Seeds* very numerous, minute, with fleshy albumen and a very small rudimentary embryo.

Distribution and Numbers.—Principally natives of Europe, Northern Asia, North America, and the Cape of Good Hope. *Illustrative Genera*:—Orobanche, *Linn.*; Lathræa, *Linn.* There are about 120 species.

Properties and Uses.—Unimportant.

Order 201. LENTIBULARIACEÆ, the Butterwort Order.—Character.—*Herbs*, growing in water, marshes, or wet places. *Leaves* radical, entire or divided into threadlike filaments

bearing little pouches or air-receptacles. *Flowers* irregular, bracteate. *Calyx* persistent, bilabiate. *Corolla* personate or bilabiate, spurred. *Stamens* 2, included; *anthers* 1-celled. *Ovary* 1-celled; *style* 1, short; *stigma* bilabiate; *placenta* free central. *Fruit* a capsule, 1-celled. *Seeds* minute, numerous, anatropous, exalbuminous; *embryo* thick, straight, sometimes undivided.

Distribution and Numbers.—Natives of all parts of the globe, but more particularly of tropical regions. *Illustrative Genera*:—Utricularia, *Linn.*; Pinguicula, *Tourn.* There are about 180 species.

Properties and Uses.—Of little importance. The leaves of *Pinguicula* and the pitchers of *Utricularia* have the property of capturing insects.

Order 202. COLUMELLIACEÆ, the Columellia Order.—Character.—Evergreen *shrubs* or *trees*. *Leaves* opposite, exstipulate. *Flowers* unsymmetrical, yellow, terminal. *Calyx* superior, 5-parted. *Corolla* epigynous, rotate, 5—8-partite, imbricate. *Stamens* 2, epipetalous; *anthers* sinuous, with longitudinal dehiscence. *Ovary* inferior, 2-celled, surmounted by a fleshy disc. *Fruit* capsular, 2-celled, many-seeded. *Seeds* with fleshy albumen; *embryo* minute.

Distribution and Numbers.—Natives of Mexico and Peru. It contains only the genus *Columellia*, Lour., which includes 3 species.

Properties and Uses.—Unknown.

Order 203.—GESNERACEÆ, the Gesnera Order.—Character. *Herbs*, or soft-wooded *shrubs*. *Leaves* wrinkled, exstipulate, generally opposite or whorled. *Flowers* irregular, showy. *Calyx* 5-partite. *Corolla* 5-lobed, perigynous or hypogynous. *Stamens* diandrous or didynamous with the rudiment of a fifth; *anthers* 2-celled, frequently united. *Ovary* of 2 carpels, antero-posterior, superior or half-inferior, 1-celled, surrounded by an annular fleshy disc or by glands; *style* 1. *Fruit* capsular or succulent, 1-celled, with 2-lobed parietal placentas. *Seeds* numerous, with or without albumen; *embryo* with minute cotyledons and a long radicle.

Division of the Order and Illustrative Genera.—The order has been divided into two sub-orders or tribes as follows:—

Sub-order 1. GESNEREÆ.—Ovary partially adherent to the calyx. Seeds albuminous. *Illustrative Genera*:—Gesnera, *Mart.*; Gloxinia, *L'Hérit.*

Sub-order 2. CYRTANDREÆ.—Ovary not adherent to the calyx.

Seeds exalbuminous. *Illustrative Genera :*—Æschynanthus, *Jack.*; Cyrtandra, *Forst.*

Distribution and Numbers.—Chiefly natives of warm or tropical regions. The Gesnereæ are all American; the Cyrtandreæ are more scattered. There are about 300 species.

Properties and Uses.—Of little importance.

Order 204. BIGNONIACEÆ, the Bignonia Order.—Character. *Trees* or *shrubs*, which are often twining or climbing, or rarely *herbs*. *Leaves* exstipulate, usually opposite. *Inflorescence* terminal. *Flowers* irregular. *Calyx* entire or divided. *Corolla* 4—5-lobed. *Stamens* 2 or 4; *anthers* 2-celled. *Ovary* seated on a disc, usually 2-celled; *placentas* axile; *style* 1. *Fruit* 2-valved, capsular. *Seeds* numerous, sessile, large, winged, exalbuminous; *embryo* with large leafy cotyledons.

Distribution and Numbers.—Chiefly tropical plants. *Illustrative Genera :*—Bignonia, *Linn.*; Tecoma, *Juss.*; Jacaranda, *Juss.* There are about 450 species.

Properties and Uses.—Unimportant.

Order 205. CRESCENTIACEÆ, the Crescentia Order.—Character.—Small *trees*. *Leaves* simple, alternate or clustered, exstipulate. *Flowers* irregular. *Calyx* free, entire at first, afterwards splitting irregularly. *Corolla* somewhat bilabiate. *Stamens* 4, didynamous, with a rudimentary fifth; *anthers* 2-celled. *Ovary* surrounded by an annular disc, 1-celled; *placentas* 2—4, parietal; *style* 1. *Fruit* indehiscent, woody. *Seeds* large, numerous, wingless, exalbuminous; *cotyledons* large, amygdaloid; *radicle* short. *This order is made a tribe of Bignoniaceæ by Bentham and Hooker.*

Distribution and Numbers.—Natives exclusively of tropical regions. *Illustrative Genera :*—Crescentia, *Linn.*; Parmentiera, *DC.* There are about 36 species.

Properties and Uses.—Unimportant.

Order 206. PEDALIACEÆ, the Pedalium order.—Character.—Glandular *herbs*. *Leaves* entire, exstipulate. *Flowers* axillary, usually large and irregular. *Calyx* 5-partite. *Corolla* bilabiate. *Stamens* didynamous with the rudiment of a fifth, included; *anthers* 2-celled. *Ovary* on a fleshy or glandular disc, 1-celled, with two parietal placentas; sometimes spuriously 4—6-celled; *style* 1; *stigma* divided. *Fruit* bony or capsular. *Seeds* wingless, without albumen; *embryo* with large cotyledons and a short radicle.

Distribution and Numbers.—Chiefly tropical plants. *Illus-*

trative Genera:—Pedalium, *Linn.*; Sesamum, *Linn.* There are about 25 species.

Properties and Uses.—Chiefly remarkable for their oily seeds.

Order 207. ACANTHACEÆ, the Acanthus Order.—Character. *Herbs* or *shrubs.* *Leaves* opposite or whorled, simple, exstipulate. *Flowers* irregular, bracteate. *Calyx* 4—5-partite, or consisting of 4—5 sepals, persistent, much imbricate; sometimes obsolete. *Corolla* more or less 2-lipped. *Stamens* 2 or 4, in the latter case didynamous. *Ovary* seated on a disc, 2-celled; *placentas* parietal, although extended to the axis; *style* 1. *Fruit* capsular, 2-celled, with a variable number of seeds in each cell. *Seeds* hanging by hard cup-shaped or hooked projections of the placenta, without wings; *albumen* none; *cotyledons* large and fleshy; *radicle* inferior.

Distribution and Numbers.—Chiefly tropical. *Illustrative Genera:*—Acanthus, *Tourn.*; Justicia, *Nees.* There are nearly 1,500 species.

Properties and Uses.—Generally unimportant; but several species are mucilaginous and bitter.

Cohort 4.—*Lamiales.*

Order 208. SELAGINACEÆ, the Selago Order.—Character. *Herbs* or *shrubs*, with alternate exstipulate leaves. *Flowers* irregular, unsymmetrical, sessile, bracteate. *Calyx* persistent, usually gamosepalous with a definite number of divisions, or rarely consisting of two distinct sepals. *Corolla* tubular, 5-partite. *Stamens* 4, didynamous, or rarely 2; *anthers* 1-celled. *Ovary* superior; *style* 1, filiform; *ovule* solitary, pendulous. *Fruit* 2-celled, with 1 pendulous seed in each cell. *Seeds* with a little fleshy albumen; *embryo* with a superior radicle. In *Globularia* there is but one carpel.

Distribution and Numbers.—Chiefly natives of the Cape of Good Hope. The species of *Globularia* are, however, European plants. *Illustrative Genera:*—Selago, *Linn.*; Globularia, *Linn.* There are about 120 species.

Properties and Uses.—Of little importance.

Order 209. VERBENACEÆ, the Vervain Order.—Character.—*Herbs*, *shrubs*, or *trees.* *Leaves* opposite or alternate, exstipulate. *Calyx* inferior, persistent, tubular. *Corolla* irregular, usually more or less 2-lipped. *Stamens* 4, usually didynamous, or rarely equal; or sometimes there are but 2 stamens; *anthers*

2-celled. *Ovary* 2—4-celled; *style* 1, terminal; *stigma* undivided or bifid. *Fruit* dry or drupaceous, composed of from 2 to 4 carpels, which when ripe usually separate into as many 1-seeded achænia. *Seed* erect or ascending, with little or no albumen, and an inferior radicle.

Diagnosis.—Known at once from the Labiatæ by their more united carpels and terminal style.

Distribution and Numbers.—They are found both in temperate and tropical regions. *Illustrative Genera :*—Verbena, *Linn.*; Clerodendron, *Linn.* There are more than 660 species.

Properties and Uses.—Many of the plants are slightly aromatic and bitter, but there are no important medicinal plants included in this order. Some are valuable timber trees; other species have fleshy fruits, which are edible; and the leaves of a few are used as substitutes for China Tea. Many are cultivated in our gardens for the beauty of their flowers or for their fragrance, as the different species and varieties of *Verbena*, the *Aloysia citriodora*, the Lemon-plant, &c.

Fig. 1171.

Fig. 1171. Pistil of the Vervain (*Verbena*).

Order 210. Myoporaceæ, the Myopora order. *Diagnosis.*—This order is sometimes regarded as a sub-order of the Verbenaceæ, from which it only differs essentially in having two seeds in each cell of the fruit, and by the embryo having a superior radicle.

Distribution and Numbers.—Chiefly natives of the southern hemisphere. *Illustrative Genera :*—Myoporum, *Banks et Sol.*; Avicennia, *Linn.* There are about 40 species.

Properties and Uses.—Unimportant. The bark of *Avicennia tomentosa*, White Mangrove, and other species, is much used in Brazil for tanning.

Order 211. Labiatæ, the Labiate Order.—Character.—*Herbs* or *shrubby plants*, with usually square stems. *Leaves* opposite or whorled, commonly strong-scented, entire or divided, exstipulate. *Flowers* generally in axillary cymes, which are arranged in a somewhat whorled manner so as to form what are called verticillasters. *Calyx* inferior, persistent, either tubular, 5- or 10-toothed, and regular or nearly so, or irregular and somewhat bilabiate; with 3—10 divisions; the odd tooth or division always posterior. *Corolla* usually more or less bilabiate, with the upper lip undivided or bifid, and commonly more or less arched over the lower lip, or sometimes nearly

suppressed; the lower lip 3-lobed, with the odd lobe anterior; or rarely the corolla is nearly regular. *Stamens* usually 4, and

FIG. 1172.

FIG. 1173.

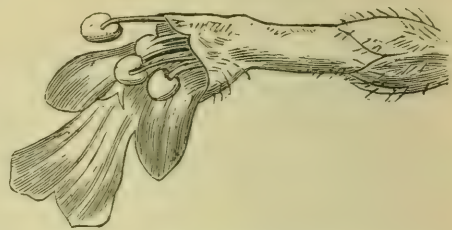


Fig. 1172. Diagram of the flower of the White Dead-nettle (*Lamium album*). *Fig.* 1173. Flower of the common Bugle (*Ajuga reptans*).

then commonly didynamous, or very rarely of nearly equal length, or only two by abortion; *anthers* 2-celled, or 1-celled by abortion; the filament or connective sometimes forked, each

FIG. 1174.

FIG. 1176.

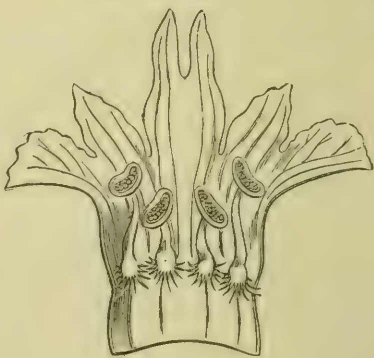


FIG. 1177.

FIG. 1175.

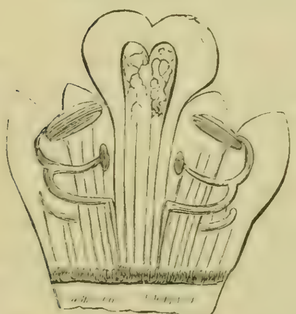


Fig. 1174. Front view of the flower of a species of *Lamium*.——*Fig.* 1175. The corolla of the Garden Sage (*Salvia officinalis*) cut open.——*Fig.* 1176. The corolla of the Horehound (*Marrubium vulgare*) cut open.——*Fig.* 1177. Lobed ovary, style, and bifid stigma of the Garden Sage (*Salvia officinalis*).

branch then bearing a perfect cell, or the cell on one side obsolete or sterile. *Ovary* inbedded in the disc or thalamus,

and formed of two carpels, each of which has 2 deep lobes, with 1 erect ovule in each lobe; *style* 1, basilar; *stigma* bifid. *Fruit* composed of from 1 to 4 achænia, enclosed by the persistent calyx. *Seed* erect, with little or no albumen; *embryo* erect, with flat *cotyledons; radicle* inferior.

Diagnosis.—Herbs or shrubby plants, with opposite exstipulate leaves. Flowers irregular, unsymmetrical. Calyx persistent. Corolla usually more or less bilabiate, with the odd lobe anterior. Stamens usually 4 and then commonly didynamous, or rarely of equal length; or only 2 by abortion. Ovary deeply 4-lobed; style 1, basilar; stigma bifid. Fruit consisting of from 1 to 4 achænia, enclosed by the persistent calyx. Seed erect, with little or no albumen; radicle inferior.

Distribution and Numbers.—Chiefly natives of temperate regions. *Illustrative Genera:*—Mentha, *Linn.*; Salvia, *Linn.*; Origanum, *Linn.*; Lamium, *Linn.* There are nearly 2,600 species.

Properties and Uses.—The plants of this large order are entirely free from any deleterious qualities. They abound in *volatile oil*, and are therefore commonly aromatic, carminative, and stimulant. All labiate plants also contain more or less of a *bitter extractive matter*, and many of them possess an *astringent principle*, hence they are frequently tonic and stomachic. Several are used in perfumery on account of their agreeable odours; and many are employed by the cook for flavouring, such as *Thymus vulgaris* (Garden Thyme), *Thymus citriodorus* (Lemon Thyme), *Salvia officinalis* (Sage), *Origanum vulgare* (Marjoram), *Majorana hortensis* (Sweet Marjoram), *Satureia montana* (Winter Savory), *Satureia hortensis* (Summer Savory), &c. The fleshy underground stems of *Stachys palustris* and of a species of *Ocymum* are edible.

Anomalous Order.

Order 212. PLANTAGINACEÆ, the Ribwort Order.—Character.—*Herbs*, generally without aerial stems. *Leaves* commonly ribbed and radical. *Flowers* usually in spikes and perfect, or rarely solitary, and sometimes unisexual. *Calyx* persistent, 4-partite, imbricate. *Corolla* dry and membranous, persistent, 4-partite. *Stamens* equal in number to the divisions of the corolla, and alternate with them; *filaments* long and slender; *anthers* versatile. *Ovary* simple, but sometimes spuriously 2- or 4-celled from the prolongation of processes from the placenta; *style* and *stigma* entire, or the latter is rarely cleft. *Capsule*

membranous, with transverse dehiscence; *placenta* free central. *Seeds* 1, 2, or more, with a mucilaginous testa; *embryo* transverse, in fleshy albumen.

Distribution and Numbers.—They abound in cold or temperate climates, but are more or less diffused over the globe. *Illustrative Genera*:—Littorella, *Linn.*; Plantago, *Linn.* There are more than 100 species.

Fig. 1178.

Fig. 1179.

Fig. 1178. Plant of a species of Rib-grass (*Plantago*), with radical leaves.——*Fig.* 1179. Flower of the same.

Properties and Uses.—Generally of little importance; but some are demulcent, and others astringent.

Artificial Analysis of the Orders in the Sub-class Gamopetalæ or Corollifloræ.

⁂ A few orders belonging to the Sub-class Polypetalæ, the flowers of which are sometimes gamopetalous, are also included in this analysis.

Ovary inferior.

A. Ovary usually 1-celled.

a. *Anthers united.*

Ovule solitary, pendulous . . . . . *Calyceraceæ.*
Ovule solitary, erect . . . . . . *Compositæ.*

b. *Anthers distinct.*

Fruit with 1 perfect cell and 2 rudimentary ones.
Seed exalbuminous . . . . . . *Valerianaceæ.*
Fruit 1-celled, and without any rudimentary ones. Seed albuminous . . . . *Dipsaceæ.*

B. Ovary with more than 1 cell.

a. *Anthers united.*

Leaves alternate . . . . . . *Lobeliaceæ.*

b. *Anthers distinct.*

1. *Stamens* 2.

Filaments not united to the style . . .	*Columelliaceæ.*
Filaments united to the style . . .	*Stylidiaceæ.*

2. *Stamens more than* 2.

Anthers opening by pores or slits . .	*Vacciniaceæ.*
Anthers opening longitudinally.	
Stigma with an indusium	*Goodeniaceæ.*
Stigma without an indusium.	
Leaves without stipules.	
Stamens definite.	
Leaves alternate. Corolla persistent	*Campanulaceæ.*
Leaves opposite. Stem round .	*Caprifoliaceæ.*
Leaves verticillate. Stem square .	*Rubiaceæ.*
Stamens numerous	*Belvisiaceæ.*
Leaves with stipules.	
Stipules interpetiolar. Flowers hermaphrodite	*Rubiaceæ.*
Stipules cirrhose. Flowers unisexual	*Cucurbitaceæ.*

Ovary superior.

Carpels more than one.

a. *Anthers opening by pores or slits* . . .	*Ericaceæ.*
b. *Anthers opening longitudinally.*	
1. Anthers 1-celled	*Epacridaceæ.*
2. Anthers 2-celled.	
Plants with dotted leaves	*Rutaceæ.*
Plants parasitic, leaves brown, scaly . .	*Monotropaceæ.*

A. Flowers regular.

a. *Ovary lobed.*	
Inflorescence helicoid. Æstivation of corolla imbricate	*Boraginaceæ.*
Inflorescence straight. Corolla with a valvate æstivation. Leaves exstipulate . .	*Nolanaceæ.*
b. *Ovary not lobed.*	
1. *Carpels more than three, distinct or combined.*	
Stamens equal in number to the petals and opposite to them.	
Stems herbaceous. Style 1. Fruit a capsule	*Primulaceæ.*
Stem woody. Style 1. Fruit fleshy, indehiscent	*Myrsinaceæ.*
Stem herbaceous or woody. Styles 5 (rarely 3 or 4). Fruit membranous .	*Plumbaginaceæ.*
Stamens not opposite the petals if of the same number.	

Carpels distinct.
Seeds numerous . . . . . . *Crassulaceæ.*
Seeds few . . . . *Anonaceæ.*
Carpels combined. Ovary 2- or more-celled.
Ovules erect or ascending.
Æstivation of the corolla plaited. Fruit dry . . . . . *Convolvulaceæ.*
Æstivation of the corolla imbricate. Fruit fleshy . . . . . *Sapotaceæ.*
Ovules pendulous or suspended, or rarely partly ascending.
Stamens twice or four times as many as the lobes of the corolla, distinct *Ebenaceæ.*
Stamens equal in number to the lobes of the corolla. Filaments distinct. Anthers adnate . . . . *Aquifoliaceæ.*
Stamens equal in number to the lobes of the corolla. Filaments distinct. Anthers versatile . . . . *Cordiaceæ.*
Some of the ovules occasionally ascending. Filaments more or less cohering . . . . . *Styraceæ.*

2. *Carpels three, combined so as to form a 3-celled ovary.*
Stem herbaceous. Disc hypogynous . . *Polemoniaceæ.*
Stem woody. No disc . . . . . *Diapensiaceæ.*

3. *Carpels two, combined or more or less distinct.*
Stamens 2 . . . . *Oleaceæ.*
Stamens 4 or more. Inflorescence helicoid.
Fruit a capsule, 1-celled or imperfectly 2-celled . . . . . . *Hydrophyllaceæ.*
Fruit drupaceous, 2- or more-celled . . *Ehretiaceæ.*
Stamens 4 or more. Inflorescence straight.
Leaves alternate.
Calyx in a broken whorl . . . *Convolvulaceæ.*
Calyx in a complete whorl.
Anthers united to the stigma . . *Asclepiadaceæ.*
Anthers free from the stigma.
Placentas parietal . . . . *Gentianaceæ.*
Placentas axile.
Æstivation of corolla valvate, induplicate-valvate, or imbricate . . . . . *Solanaceæ.*
Leaves opposite, whorled, or clustered.
Anthers united to the stigma . . . *Asclepiadaceæ.*
Anthers free from the stigma.
Leaves with stipules . . . . *Loganiaceæ.*
Leaves without stipules.

Stigma shaped like an hour-glass.
Æstivation of corolla contorted . *Apocynaceæ.*
Stigma not contracted in the middle like an hour-glass.
Æstivation of corolla imbricate, placentas parietal . . . *Gentianaceæ.*
Æstivation of corolla valvate, placentas axile . . . . *Stilbaceæ.*

4. *Carpel solitary.*
Stamens opposite the lobes of the corolla or petals . . . . *Plumbaginaceæ.*
Stamens alternate to the lobes of the corolla.
Fruit 1-celled. Stigma sessile . . . *Salvadoraceæ.*
Fruit spuriously 2-celled or rarely 4-celled. Style capillary . . . . . *Plantaginaceæ.*

B. Flowers irregular.

a. *Ovary 4-lobed* . . . . *Labiatæ.*

b. *Ovary not lobed.*

1. *Carpel solitary* . . . . . . *Selaginaceæ.*

2. *Carpels two.*
Fruit hard or nut-like.
Anthers 1-celled . . . . . . *Selaginaceæ.*
Anthers 2-celled. Ovules erect.
Corolla imbricate in æstivation . . *Verbenaceæ.*
Corolla valvate in æstivation . . . *Stilbaceæ.*
Anthers 2-celled. Ovules pendulous . *Myoporaceæ.*
Fruit capsular or succulent.
Placentas parietal.
Leafless scaly, brown, root-parasites . *Orobanchaceæ.*
Leafy plants. Seeds with wings . . *Bignoniaceæ.*
Leafy plants. Seeds without wings.
Fruit a capsule or baccate. Cotyledons minute, radicle long . . . *Gesneraceæ.*
Fruit bony or a capsule. Cotyledons large, radicle short . . . *Pedaliaceæ.*
Fruit woody with a pulpy interior. Cotyledons large, radicle short . *Crescentiaceæ.*
Placentas axile.
Seeds without wings.
Albuminous . . . . . . *Scrophulariaceæ.*
Exalbuminous. Seeds attached to hard placental processes . . *Acanthaceæ.*
Seeds winged. Exalbuminous . . *Bignoniaceæ.*
Placentas free central . . . . *Lentibulariaceæ.*

There are many exceptions to the characters above given of the Gamopetalæ or Corolliforæ. Thus, among the Inferæ or Epigynæ we sometimes find polypetalous corollas in *Caprifoliaceæ* and *Lobeliaceæ*, and the ovary

is sometimes superior in *Goodeniaceæ*. In the Superæ and Dicarpiæ, polypetalous species are sometimes found in *Ericaceæ*, *Monotropaceæ*, *Epacridaceæ*, *Styraceæ*, *Oleaceæ*, *Primulaceæ*, *Myrsinaceæ*, and *Plumbaginaceæ*.

Again, among the Superæ and Dicarpiæ we occasionally find the ovary inferior, or partly so, as in *Ebenaceæ*, *Styraceæ*, *Myrsinaceæ*, *Primulaceæ*, and always in *Gesneraceæ* and *Vacciniaceæ*.

In *Oleaceæ* and *Primulaceæ*, apetalous species sometimes occur; and unisexual species are also occasionally found in *Valerianaceæ*, *Compositæ*, *Ebenaceæ*, *Myrsinaceæ*, and *Plantaginaceæ*, and other exceptions have been already noted.

Synopsis of the British Natural Orders of the Sub-class Gamopetalæ.

A. Corolla gamopetalous, superior.
  Stamens inserted beneath epigynous disc . . *Vacciniaceæ.*
  Stamens inserted with the corolla and free from it.
    Filaments free . . . . *Campanulaceæ.*
  Stamens epipetalous, alternate with lobes of corolla.
    Anthers united, flowers in capitula . . . *Compositæ.*
    Anthers free.
      Inflorescence a capitulum. Calyx with involucel . . . . *Dipsaceæ.*
      Flowers corymbose or cymose.
        Fruit with a double indehiscent pericarp, 2-celled, 2-seeded . . . . . *Rubiaceæ.*
        Fruit dry, with 1 perfect and often 2 abortive cells . . . . . . *Valerianaceæ.*
        Fruit fleshy, with 1 or several seeds . *Caprifoliaceæ.*

B. Corolla gamopetalous, inferior.
  Ovary and fruit 4-lobed. Style gynobasic.
    Stamens 5. Corolla regular. Leaves alternate *Boraginaceæ.*
    Stamens 4 or 2, corolla irregular, leaves opposite *Labiatæ.*
  Ovary and fruit simple. Style terminal.
    Ovary 1-celled, 1-seeded. Stamens antipetalous. Styles 5 . . . . . *Plumbaginaceæ.*
    Ovary 1-celled, many seeded.
      Corolla scarious, regular. Stamens 4 . . *Plantaginaceæ.*
      Corolla coloured.
        Corolla irregular.
          Stamens 2 . . . . *Lentibulariaceæ.*
          Stamens 4, didynamous . . . . *Orobanchaceæ.*
        Corolla regular. Stamens antipetalous . *Primulaceæ.*
    Ovary 2- or more-celled (fruit sometimes 1-celled).
      Stamens hypogynous, distinct . . . . *Ericaceæ.*
      Stamens epipetalous.
        Stamens 2. Corolla regular . . *Oleaceæ.*

Stamens 2 or 4, didynamous. Corolla irregular.	
Ovary 2-celled, not lobed. Placentas axile	*Scrophulariaceæ.*
Ovary 2—4-celled, lobed . . .	*Verbenaceæ.*
Stamens 4 or 5, not didynamous.	
Cells of ovary each with 1 or 2 ovules.	
Fruit a capsule	*Convolvulaceæ*
Cells of ovary each with many ovules.	
Fruit a double follicle . . .	*Apocynaceæ.*
Fruit 2- or imperfectly 4-celled. Leaves alternate	*Solanaceæ.*
Fruit 1- or imperfectly 2-celled. Leaves opposite	*Gentianaceæ.*
Fruit 3-celled	*Polemoniaceæ.*

BOOK IV.

PHYSIOLOGY OF PLANTS.

CHAPTER I.

THE RELATION OF WATER TO THE PROTOPLASM OF THE CELL.

We have already seen in considering the structure of both simple and complex plants, that they are all composed originally of a variable number of protoplasts, which are in close relationship with each other, being partially separated in most cases by septa, or partitions, known as cell-walls. The latter show a great deal of variety in the way they are arranged, their thickness, the material of which they are composed, &c. The protoplasts, on the other hand, resemble each other in all essential particulars, though in complex plants one or other function or property of each is often developed to a greater extent than the remainder which it possesses.

The essential difference between the protoplasm of the plant and the walls by which it is supported lies in the fact that the former is the living substance, by whose activity all the remainder is constructed. In dealing with the physiology of the plant, we have therefore to turn our attention to the protoplasm. We have seen that in the simplest forms of plant this may exist without any cell membrane, and may be freely motile, swimming in water by means of cilia, or creeping in a semi-animal fashion by pseudopodia. In other unicellular plants it may be surrounded by a cell-wall, and may either entirely fill the space afforded inside the latter, or may have inside itself a vacuole. In the multicellular plants, each cell while living shows its own protoplast or aggregation of the protoplasm, which is probably connected always with that of the adjoining cells. The protoplasm generally lies as a peripheral layer round the outside of the cell, though in many cases the central cavity is crossed by a number of bridles passing generally from a somewhat central

spot to the periphery. A nucleus is a constituent of all cells when they are young, though in some few cases it disappears later. It is always embedded in the protoplasm, of which it is a specially differentiated portion.

Not only does the living substance construct the substance of the plant originally, but it is the part by which the organism is able to place itself in harmony with its environment. It assimilates the food the plant requires and carries out the chemical processes incident to its life; it receives impressions from without and regulates the response the plant makes to these impressions, both by internal and external movements or changes of position; finally it carries out the reproductive processes.

Looking at the arrangement of protoplasm in the cell, or at its environment in the free condition, we notice especially its very close relation to water. The free-swimming zoospore is naturally saturated with the latter, being in the fullest contact with it. The young cell enclosed in its cell-membrane speedily shows a tendency to accumulate water in its interior, and gradually drops appear, which lead ultimately to the formation of a vacuole always full of liquid. The healthy protoplasm is thus always in contact with water. Indeed the molecular constitution of protoplasm, as far as we know it, lends itself to this relation, for the apparently structureless substance is always saturated with it. It is only while in such a condition that the cell can live; with very rare exceptions, if a cell is once completely dried, even at a low temperature, its life is gone, and restoration of water fails to enable it to recover.

The constancy of the occurrence of the vacuole in the cells of the vegetable organism is itself an evidence that such cells manifest their dependence upon water for the maintenance of life. The cell-wall, though usually permeable, yet presents a certain obstacle to the absorption of water, and so even those cells which are living in streams or ponds usually possess a vacuole. Cells without a membrane, such as the zoospores already many times mentioned, can more readily absorb water from without, and hence they are not vacuolated to the same extent as the former ones; indeed, many of them have no vacuole. This cavity being always filled with liquid, the protoplasm of the cell has ready access to water, as much so indeed as the cell which possesses no wall. The vacuole contains a store which is always available.

We have seen that the presence of water is necessary to the life of the cell, and that a store of it is usually contained in its

interior. As this must be absorbed from without, it becomes necessary to inquire into the way in which it effects its entry. This is based upon a purely physical process which is known as *osmosis*. If two fluids of different densities, for example water and syrup, be separated from each other by a homogeneous permeable membrane, they will tend to pass through the latter till there is a mixture of the two of equal density on each side of it. We shall thus have a stream of water passing through the membrane to the syrup, and a stream of syrup similarly passing to the water. The rate of flow of the two streams will not be the same, however, and the first result will be a considerable increase in quantity of the fluid upon the side of the membrane in contact with the syrup, owing to the greater amount of water that will have passed through.

A convenient form of apparatus to exhibit this process of osmosis is shown in *fig.* 1180. It consists of a bladder fastened to the end of a narrow tube, which is immersed, as shown, in a vessel of water. The bladder and part of the tube are filled with syrup, and the height at which the latter stands in the tube is noted. After some time the contents of the tube will be increased, and the liquid will stand in it at a higher level, in consequence of the osmotic action that has taken place. If the positions of the water and the syrup were reversed, the liquid would fall in the tube, showing that under these conditions also there is a greater stream of water towards the syrup than of the latter in the opposite direction.

FIG. 1180.

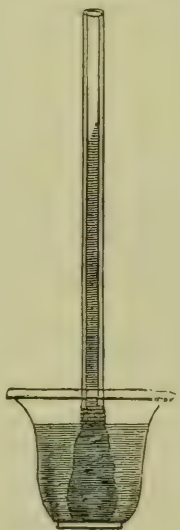


Fig. 1180. Apparatus to show *osmotic action*. It consists of a bladder filled with syrup to the open end of which a tube is attached, and the whole placed in a vessel containing water.

Though the process thus stated is far simpler than what we have reason to believe takes place in the vegetable cell, we can apply it to explain the original formation of the vacuole. Consider the case of a cell of the dermatogen of a plant which is immersed in water. It is full of protoplasm, and limited or clothed by a cell-membrane, which is permeable more or less readily by water. The protoplasm is saturated with water, but there is no separate accumulation of the latter. Part at least of

the cell-wall is in contact with water on the outside. The protoplasm is actively living, and in the course of the chemical changes which are incident to vital action, certain substances are produced by it, which, like the syrup in the experiment detailed, have an affinity for water, or, to use a more technical phrase, have a fairly high osmotic equivalent. Water consequently passes into the cell, at first only in such quantities as to somewhat distend it. As the process goes on, more liquid is present than can be stored in the molecular interstices of the protoplasm. Drops consequently appear, and these gradually run together until a distinct though small vacuole, or a number of such vacuoles, is apparent in the protoplasm. By a continuation of the process the protoplasm ultimately forms a layer round the cell-wall, enclosing the large cavity in which the surplus liquid is held.

But, as has already been said, the process is not a simple physical one. Though the conditions of the first experiment are approximated to, they are not altogether realised. The syrup in the bladder finds its representative in the osmotic substances formed by the protoplasm and dissolved in the water in its meshes; the water outside the cell is the same as the water in the outer vessel. But there is a great difference in the membrane. The bladder of the experiment is replaced by a film of cellulose lined by the protoplasm itself. The former is readily permeable, but the latter is not. A further experiment will show a very important modification of the process, brought about by the protoplasm, and demonstrating that the entry of water into the cell is very largely under the regulation of the latter.

Take a cell of the cortex of the plant and put it in contact with a liquid of higher osmotic power than its own contents; for instance with a solution of common salt, containing 5—10 per cent. of the crystals. Watch its action on a slide under the microscope, and let the salt solution be coloured with some vegetable dye which will not injure the living substance. As the salt solution reaches the cell, the protoplasm of the latter gradually retreats from the walls, at first at the corners and then all round the sides, till it appears as a rounded mass in the centre. The salt solution has abstracted the water from the vacuole, and the protoplasm, relieved of the outward pressure caused by the liquid in the latter, has shrunk away from the walls. The outward stream has been accompanied by an incoming one as in the first experiment. The coloured salt solution will be seen inside the cell-wall, between it and the protoplasm. But here is a great

difference between the two experiments ; the salt solution does not pass through the protoplasm, though it does go through the cell-wall. If, now, the salt solution be replaced by water, the latter is gradually attracted again, of course osmotically, into the cell. It passes through the protoplasm ; the vacuole is re-established, and the protoplasm again comes to line the cell-wall, pressed against it by the water.

The protoplasm thus allows water to pass through its substance, but can oppose the passage either way of the various osmotic bodies with which it may be brought into contact. In the last narrated experiment it prevented the salt solution from entering the vacuole, and, as shown by the return of the water into the latter, it prevented the osmotic substances originally in no the cell from leaving it.

That this is due to the vital power of the protoplasm can be shown by repeating the experiment after killing the living substance by a short immersion of the cell in alcohol. Then the process of osmosis goes on exactly as in the first experiment quoted. The salt solution penetrates into the vacuole as if only a cellulose septum were present. the dead protoplasm exerting no regulating influence.

The modified osmosis, which is thus the mode of entry of water into a cell containing no vacuole, continues after the vacuole is formed, and is the cause of the transfusion of water from cell to cell. We can see that this must be the case, for if two cells are considered which are separated from each other by a common cell-wall, it is evident that, unless the proportion of water to osmotic substances in the vacuoles of both is the same, osmotic currents will flow from one to the other till this equilibrium is reached.

The quantity of osmotic substances present in any cell will depend upon the behaviour of the protoplasm from time to time. Such substances are usually being continually produced in all growing cells and in most others in which chemical changes are proceeding. Hence such cells are continually absorbing water, and are consequently so full that a certain stretching force is exerted on the cell-wall which bounds them. Cells in such a condition are called *turgid*, and the condition itself is known as *turgescence*. The equilibrium, which is attained by such a cell, is reached when the distension caused by the osmotic substances is balanced by the elastic recoil of the extensible cellulose wall. In some cases the tension set up in a tissue by the turgescence of the cells is sufficient to force the water. by a process of filtration, through the walls of the outermost ones, so

that it escapes in drops or in a slow stream. This may often be seen on the edges or apices of blades of grasses in the early morning. It is of great use also in forcing water into the axial woody cylinder of roots, as will appear later. Occasionally the turgescence becomes so great as to lead to rupture of the cell-walls, as is the case sometimes in fleshy fruits.

That the condition of turgidity in cells is attended by a stretching of the cell-walls can be seen by taking a piece of a plant which is turgid, such as the stalk of a rhubarb leaf, and, after carefully measuring its dimensions, steeping it for some time in a 10 per cent. solution of salt. On removing it, it will have become flaccid, and a remeasurement will show that both its length and thickness have diminished. Turgescence is not, however, solely due to physical causes; the protoplasm which lines the cells has a regulating influence over the passage of the water in and out of the cell. If a turgid pulvinus of such a plant as *Robinia*, or *Mimosa*, be stimulated by rough handling of the leaf, the latter falls from its expanded position towards the stem, and the fall is found to be due to the escape of water from the cells of the lower side of the pulvinus. The original state of equilibrium has been disturbed by the shock to the protoplasm administered by the stimulation, and the latter allows water to pass outwards.

The active influence of the protoplasm is seen also in another class of phenomena. Certain structures known as nectaries have been described as occurring in many flowers. These are aggregations of cells of a particular kind which exude a sugary fluid upon their surfaces. If the petals of certain flowers bearing these nectaries be cut off and their cut ends immersed in water, the glands continue for some time to exude the nectar. There can be no question here of any filtration of water through the tissue, as there is no pressure acting on the base of the petal. The protoplasm causes the stream to continue to flow by producing osmotic substances, in this case chiefly sugar. It differs still more in its behaviour in that it pours out not only the water thus absorbed, but a certain amount of the sugar in addition. If the gland be killed by alcohol, the sugar already there is retained in the cells, and no exudation of nectar or even of water takes place.

The vital activity of the protoplasm is thus seen to be intimately connected with the presence of water in its substance. The importance of the ready access of the latter is seen further from other considerations. In the foregoing pages we have

spoken of it as if it were pure water only; this is. however, not the case, for the water, when absorbed, contains small quantities of various substances in solution. Though the protoplasm opposes the entry of anything like a strong solution of inorganic salts, say 5 to 10 per cent., it allows very dilute ones to enter much as it does pure water. In this way the slowly diffusing stream brings to the protoplasm of each cell the inorganic materials which are absorbed from the earth, and enables the matters elaborated or formed from them by the protoplasm to pass from cell to cell. The feeding or nutrition of the various cells is thus dependent on the transit of fluid about the plant in the way described. The access of various gases is similarly made possible, for these are dissolved in the liquid stream. Thus the oxygen, upon the presence of which life depends, is transported to each cell, and the carbon dioxide of respiration is removed from the seats of its liberation. The condition of turgescence is necessary also for growth and for various movements of different parts, enabling them to adapt themselves to varying conditions of their environment. Some plants, particularly those which are aquatic in habit, and such parts of terrestrial plants as have but little woody tissue, are dependent upon the turgidity of their cells for the rigidity which enables them to retain their positions in the medium in which they live.

The importance of the water supply, and, indeed, its necessity to the plant, explains the presence of the aqueous tissue which we have seen to occur in various parts. The cells of this tissue contain little else than water, and may be regarded as an additional reservoir, supplementing the vacuoles of the ordinary cells. In plants that inhabit dry arid soils, such as sandy deserts. there are often other adaptations relating to water storage. Such plants are often covered with large bladder-like hairs, which hold a considerable quantity of liquid. In many plants the epidermal cells form a further reservoir. Plants exposed to conditions threatening too copious evaporation are generally furnished with a very prominent cuticle, tending to check undue escape.

CHAPTER II.

THE TRANSPORT OF WATER IN THE PLANT.

We have seen that it is necessary for the life of the plant that all its living cells shall be freely supplied with water. According to the habit of life of plants the mode of supply must necessarily vary. Those which are so constituted that water finds free access to all the cells, such as the unicellular or filamentous algæ, which live in streams, pools, &c., present no difficulty, as osmosis can go on freely in each cell. Sturdier plants of aquatic habit are almost equally easily supplied; the water enters by osmosis into the epidermal cells, which we have already seen are provided with membranes that are not cuticularised, and it can pass readily from cell to cell all over the plant body. Plants of terrestrial habit, from the nature of their environment, require a more elaborate mechanism, which is found in the large development of woody tissue they exhibit. Throughout all such plants a stream of water passes, entering in at the roots, passing along the woody axis of the root, up the stem into the leaves, where a very large part of it is evaporated. This stream of water is often known as the *ascending sap*. In addition to this comparatively rapid stream, slow currents of diffusion from cell to cell are also maintained as in the plants of humbler development.

Except in some special cases, the water which passes through the body of an ordinary land plant is obtained from the soil in which its roots are embedded. The soil itself is composed of minute particles of inorganic matter, derived originally from the breaking down of rocks, and of decaying animal or vegetable matter mixed with the inorganic constituents. This organic matter is known as *humus* and is of very varied composition. The soil thus consists of a loose matrix of granular character, the interstices of which are normally filled with air, but which can contain varying quantities of water. When these spaces are filled with water, the plants growing in the soil are very unfavourably placed for absorbing it. When air is present in them, each particle of soil is surrounded by a delicate film of water, which adheres closely to it. This water, often spoken of as *hygroscopic* water, is the source of the plant's supply. It adheres so firmly to the soil particles that it escapes ordinary observation; if, however, soil which has been allowed to dry at any ordinary

temperature till its interstices are apparently empty be exposed to a heat approaching that of boiling water, a considerable quantity of vapour will be given off, due to the volatilising of the hygroscopic films.

We have seen that the youngest roots and rootlets are furnished near their apices with a number of delicate hairs (*fig.* 1181) or outgrowths of their epidermal cells (*fig.* 1182), which make their way into the interstices of the soil. Not only do these play a very important part in anchoring the plant to the substratum, but they are the means by which the water is absorbed. The delicate walls of these root-hairs come into the closest relationship to the particles of soil, pressing in some cases

Fig. 1181.

Fig. 1182.

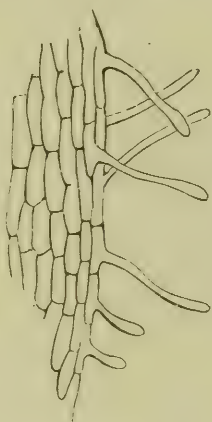


Fig. 1181. Ultimate branches of a root, showing position of root-hairs.——*Fig.* 1182. Root-hairs on the surface of a young root.

so closely upon them, that the particles are embedded in the membrane. The hygroscopic film of water is so separated from the interior of the root-hair by a most delicate pellicle of almost pure cellulose. The cell-sap in the hair contains a certain amount of acid in solution, and by virtue of this osmosis is set up. The root-hairs, which are very numerous, become turgid, and by continued osmosis the water is passed inwards to the cortex of the root, all the cells of which soon exhibit considerable turgescence, thus causing a great deal of hydrostatic pressure in the cortex. At the places where the latter abuts upon the xylem elements of the stele a filtration under this pressure takes place, so that the water is forced into the axial woody tissue.

The filtration when set up tends to relieve the pressure in the cortex, and additional water can then be absorbed as before. The water is thus made to rise gradually in the axial stele, for the root-hairs and the cortical tissue exert together in this way a kind of pumping action, forcing it along the axis. This force, due to the turgescence set up as described, is known as *root-pressure*, and is one main factor in the transport of water through the plant. The turgescence not only leads to the rise of sap in the axial stele, but spreads throughout the whole of the cortical tissue of the plant, reaching indeed every cell into which osmotic diffusion can take place.

The stele of the root we have seen to be directly continuous with that of the stem, the woody elements being in contact throughout. The stream of water consequently passes up the woody tissue of the stem so long as the cells are living. The hard dead wood of the duramen takes no part in the conduction, which is confined to the alburnum. Some discussion has taken place as to the exact path followed, but that the one indicated is that which is taken has been proved by cutting incisions round the trunks of trees to various depths. So long as the alburnum is not cut the stream is not interrupted, but if the wound passes through that region it stops, and all parts of the tree above the incision droop and die.

The water has been said by some observers to pass along the cell-walls of the woody vessels and tracheïds, and not through their interior. Other writers hold that the main stream travels along the interior of the cells. To this point we shall return later. In either case the water ascends through the trunk, branches, and twigs of the tree till it reaches the points at which the foliar meristeles leave the central axis. It passes along the woody elements of these, entering the leaves thus by the fibro-vascular bundles or veins. From these it makes its way to the parenchymatous mesophyll of the leaves, the cells of which are thus made turgid. Osmotic diffusion, interrupted in the axis of the plant, is resumed in the leaves, and a general equilibrium of turgescence is reached in them.

We have seen that the parenchyma of the leaves, and particularly that of the lower half of each, is abundantly supplied with intercellular spaces (*fig.* 1183). The cells which abut upon these spaces are furnished with very delicate walls and readily allow a process of evaporation to take place, watery vapour passing into these passages. The surface of the leaf we have seen to be furnished with a number of openings or stomata,

each communicating with the system of intercellular spaces, and having two guard-cells surrounding it. Through these stomata the watery vapour evaporated into the intercellular spaces passes to the external air, the quantity escaping being regulated by the degree to which the guard-cells are approximated. We have thus a copious evaporation taking place from the surface of the leaves, which plays an important part in causing the flow of water through the plant. This evaporation is known as *transpiration* and must be discussed more fully later.

Little or no evaporation takes place from the surface of the epidermis of the leaves, the cells of which have their outer walls generally strongly or weakly cuticularised, the cuticle offering considerable resistance to the passage of water, or watery vapour, in either direction.

FIG. 1183.

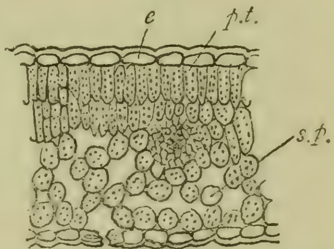


Fig. 1183. Section of leaf of *Beta*. *e*. Epidermis. *p.t.* Palisade tissue. *s.p.* Spongy parenchyma with large intercellular spaces.

The escape of water is thus mainly brought about by evaporation into the intercellular spaces of the leaves. It is not confined, however, to these, but takes place generally into all the intercellular spaces, which form a system of minute channels permeating the whole plant. The actual escape from the plant takes place wherever there are stomata, as well, that is, from the young green twigs as from the leaves themselves. It is supplemented in some cases by an actual excretion of water as such, carried out by means of the water glands we have seen to occur in some plants at the ends of some of the veins of the leaves. When the hydrostatic pressure is very high at times in herbaceous plants, water may be forced out of the tips of the leaves without the intervention of glands.

The stream of water thus passing through the plant has a very important influence upon its development. This is evident from the consideration that a large part of the food of the plant is absorbed by means of this stream, the water containing minute proportions of the various nutritive salts which exist in the soil. The quantity passing is further correlated with the amount of leaf surface which the plant presents; where there is a large leaf area there is copious transpiration; this necessitates a larger path for the ascending stream and a consequent development of

the axial portions of the plant. Where there is a large flow of water, as in a tree, there is a continuous formation of material; where the transpiration is but slight, as in a Cactus, there is but little formation of new plant substance.

CHAPTER III.

THE SKELETON OF THE PLANT.

We have seen that the protoplasm of the plant is a soft almost jelly-like substance, incapable of resisting any considerable disturbing force or pressure, such as almost all plants are inevitably exposed to, whatever be the nature of their environment. To enable them to cope with the difficulties presented by the latter, plants must possess a certain rigidity, which varies with the nature of their situation. The soft protoplasm must consequently be supported by something which will secure this rigidity. The several protoplasts are in most cases surrounded by a cell-wall or membrane which subserves this purpose. According to the habitat of each plant the development of its cell-membranes shows various degrees of complexity, and many modifications of the original structure are found. We have already seen that such modifications take the forms of alteration of the shape of the cell, of aggregations of cells in various ways, and of differences of chemical constitution brought about as the age of the cell increases. These differences are not merely connected with the maintenance of rigidity, but subserve also various functions which the different tissues of complex plants perform.

In the simplest plants, consisting of single cells, or rows or plates of cells, and living in water, but little rigidity is needed. The unthickened cell-wall is here sufficient, when combined with the turgescence of the cells, to prevent their being destroyed by the ordinary antagonistic influences which they have to encounter. The form of the plant is also modified to enable it to survive such difficulties. Plants growing in rapidly flowing water usually have flexible stems and much divided leaves, which consequently give way to the current and escape damage. Those of terrestrial habit, on the other hand, exposed to winds and storms, are furnished with considerable development of woody roots which anchor them securely to the earth, and with sturdy trunks consisting of masses of wood, which secure stability even when atmospheric disturbances are severe. The

subdivisions of the trunk, ending in finely divided twigs, while exposing considerable surface to the air, present on the whole a fairly yielding plant body, through which the currents of air can make their way without meeting such a resistance as to cause the uprooting of the tree. In other forms a weak stem of considerable length exists, which obtains support by clinging in various ways and holding by various mechanisms to some other structure, such as the trunks of trees, rocks, walls, &c. In these the woody development, though considerable, is much less than in ordinary trees.

The leaves show similar adaptations of structure to environment. The venation of the leaves, though mainly subserving the purpose of transport of liquids, is yet often such as to afford considerable resistance to damage from strong winds. Often the veins are so arranged as to form a series of arches on the external margins, preventing lateral tearing. The epidermal cells of many leaves frequently exposed to intense cold are strongly cuticularised, and the rigidity thus afforded is sometimes supplemented by a development of hypodermal sclerenchyma.

All these arrangements may be regarded as affording a supporting skeleton to the plant, the nature of which and the degree of its development can only be understood by a consideration of the habit of life of the plant under examination and the dangers to which its environment exposes it.

The ordinary cell-wall of the cell as it is first formed is a clear, transparent, extensible and elastic membrane, which is secreted by the protoplasm and which remains in contact with it so long as the cell is living. It is capable under certain conditions of absorbing considerable quantities of water, and in consequence swelling considerably. It is usually said to be composed of a substance named *cellulose*, whose chemical composition is represented by the formula $n\ (C_6H_{10}O_5)$, the value of n not yet having been exactly determined. This substance is related to such bodies as starch, sugar, &c., being a member of the group of *carbohydrates*. It is capable, under the action of certain reagents, of being converted into a form of sugar, and under certain circumstances it can yield nutritive material for the use of the living substance.

Probably, however, the cell-wall is in very few cases altogether composed of pure cellulose, but mixed with the latter, certain bodies occur which are compounds of pectic acid with lime. There are many such bodies, but our knowledge of them is very imperfect, nor is their respective distribution at

all well understood. Certain solvents will extract them from ordinary cell-walls, leaving cellulose as the basis of the latter.

The reactions of cellulose have been already described in an earlier section in dealing with the composition of the cell-wall. The most characteristic one is the assumption of a blue colour when treated with iodine and some hydrating agent, such as strong sulphuric acid or chloride of zinc.

Cellulose itself is capable of existing in more than one condition. We find some kinds of it which will stain blue on treatment with iodine alone. Examples are found in the cell-walls of the bast of the stele of Lycopodium, the endosperm of the Pæony, the cotyledons of some of the Leguminosæ, &c. The walls of the hyphæ of the Fungi differ again, in that they will not give the blue colour with iodine even after treatment with hydrating agents. Recent observations suggest that this variety of cell-wall approaches in composition the chitin of the animal kingdom.

It is probable that cellulose is chemically combined with a certain amount of water, and that the degree of hydration differs in the different varieties described.

Where considerable rigidity of structure is needed it is obtained by the conversion of the cellulose into *lignin*, the material found conspicuously in the walls of wood cells. This is formed in the substance of the cell-walls, and in partially lignified membranes the lignin can be dissolved out, leaving a cellulose basis. In its chemical characters lignin differs materially from cellulose; it has no extensibility, nor can it absorb water and swell as can the latter; on the other hand it allows water to pass through it with great rapidity and ease. It can be recognised micro-chemically by staining red when treated with phloroglucin and a mineral acid, or yellow with aniline chloride under the same conditions.

Lignin is probably not a definite chemical compound, but a mixture of substances successively formed from the cellulose. Its physical properties render it particularly adapted to serve as the material of which the tissues conducting the stream of water are composed. Its lack of flexibility or extensibility makes it suitable for the securing of rigidity in tissues or structures needing strong power of resistance to winds or storms.

The modification of the tegumentary tissue of the higher plants takes the form primarily of the transformation of the cell-wall into *cutin* or *suberin*, the former being characteristic of the outer layers of the epidermal cell-walls, and leading

to the peculiar properties of the cuticle. Suberin is the substance found in great proportion in the walls of corky cells. Both of these are formed like lignin by modification of cellulose. They serve rather to prevent undue evaporation than to act as a true skeleton. In old trees, however, the complex barks, into the composition of which cork enters to a very considerable extent, often subserve somewhat the purpose of aiding in the mechanical support of the tree, especially in cases where the woody centre decays and the tree becomes hollow.

In many cases the cell-walls, while remaining chemically unchanged, become impregnated with silica or other mineral matter. The cereal grasses and the Equisetaceæ accumulate copious quantities of silica in the walls of their epidermal cells. Though this appears not to be altogether essential to their power of remaining upright, it no doubt materially assists it.

Other modifications of cellulose are found in various cell-walls, but they are comparatively unimportant from the point of view now under discussion.

Where the ordinary unmodified cell-walls of the plant are not sufficient to secure rigidity, as in most terrestrial plants, there is a very varied distribution of tissues for that purpose. The forms which are found are collenchyma, sclerenchyma, and vascular tissue, the former two appearing to subserve mechanical purposes only, while the latter also takes part in the transport of water. In delicate stems but little development of either is seen; thus most moss plants show in their axis only the hypodermal cells thickened, while this is supplemented in the *Polytrichaceæ* by a central core of somewhat lignified cells. In succulent petioles there is a hypodermal development of collenchyma, in addition to the meristeles, which contain a certain amount of wood. In many herbaceous stems, particularly those with angles, strands of sclerenchyma are found underlying part or the whole of the margins. In many Monocotyledons of humble growth the centre of the stem is hollow or is occupied by thin-walled fundamental tissue, sometimes made of stellate cells, and the margin is strengthened by strands of sclerenchymatous fibres placed behind or between the fibro-vascular bundles.

Plants of larger growth depend very largely on the fibro-vascular part of the stele for their supporting tissue. This is seen most easily in the trees belonging to the Gymnosperms and Dicotyledons, which increase regularly in thickness. Large monocotyledonous trees depend upon the same class of elements, though the distribution of the individual bundles is different.

In many members of these groups, and in many of the Pteridophytes the fibro-vascular system is not so well developed, and we find in such plants the stereome is supplemented by the appearance of bands or sheaths of sclerenchyma very variously disposed. There is usually a considerable hypodermal development, besides masses occurring more deeply in the axis. Sometimes the cortical ground tissue contains isolated sclerenchymatous bands, often of large size; frequently the pericycle has similar developments. Sometimes, again, the sclerenchyma, instead of being in isolated strands, forms a continuous ring or sheath. Many stems contain developments in all three regions which are variously connected together.

The arrangements of stereome tissue in the leaves are similarly varied. The meristele of the petiole is frequently found to have a large amount of sclerenchyma in its pericycle, and this is continued upwards along the chief axis or axes of the epipodium, gradually thinning out as the margin is approached. In the large flattened leaves of some Monocotyledons, bands of sclerenchyma frequently extend completely across the interior. In some leathery leaves large idioblasts of various form act as struts or trabeculæ, reaching from one epidermis to the other. The arrangement of the veins in many leaves has already been alluded to.

The root usually depends for its rigidity upon the great development of fibro-vascular tissue in the stele. As we have seen, the tissues external to the endodermis are not as a rule long-lived, and hence the bulk of an adult root is stelar in origin. Aquatic roots, like the stems of the same plants, have but little development of specially supporting tissue, but owe their rigidity to the turgescence of their cortex.

CHAPTER IV.

THE TRANSPIRATION CURRENT—ROOT PRESSURE—TRANSPIRATION.

We have seen in Chapter II. that in terrestrial plants, so long as circumstances are favourable to the vital activity of the organism, a stream of water is passing from the roots through the axis to the green twigs and leaves, where the greater part of it is evaporated. This current has been called the *transpiration* current, and its rate has been ascertained to be on an average about 100 centimetres per hour. The path by which it passes

has been shown to be the young wood of the axial stele, into which it is forced by a kind of filtration from the over-turgid cortical tissue of the root. The wood vessels and tracheïds form a closed system, quite separated from the atmosphere, containing air and a certain quantity of water. Sometimes they are filled with the latter, often they contain a much larger quantity of air. In no case probably are they during life free from either, though the proportions of the two vary very greatly. Much controversy has arisen as to whether the transport of the water takes place through the substance of the cell-walls or through the cavity of the vessels and tracheïds. The character of the former suggests that very possibly water may be carried through them; that indeed the structure may be regarded as a column of water held together by the molecules of the lignified walls. This view is supported by the behaviour of lignin, which while refusing to absorb much liquid and swell, as cellulose does, yet can contain a certain quantity which it will part with very easily. On the other hand compression of the vessels by a vice, if carried so far as partially or entirely to obliterate their cavities, materially interferes with the rate of flow.

Two main causes appear to co-operate in maintaining this upward stream. We have the constant pumping action of the cortex of the root, giving us the force known as *root-pressure*. We have also the modified evaporation from the surface of the green parts of the plant, which we have spoken of as *transpiration*. Both these may now be discussed in greater detail. Besides these two, other factors have been held to co-operate, though much less certainly than they. The walls of the vessels having extremely narrow calibre, capillarity has been suggested as playing a part. This cannot, however, have much effect in a system of closed tracheïds, like those of the secondary wood of the Conifers, which nevertheless conduct the water. It has been thought that the living cells of the parenchyma which abut upon the woody tissue of the stele may play a part similar to the pumping action of the root. Against this theory we have the fact that if the transpiration current be made to contain substances that are poisonous to the living cells, and the latter are consequently killed, the current still goes on. Nor do differences of gaseous pressure within and without the plant, or at different portions of the axis, explain the matter more satisfactorily.

Root-pressure.—We have shown how the absorption of water

osmotically from the soil by the root-hairs leads to a great turgescence of the tissue of the cortex of the root, which turgescence exerts considerable pressure on the sides of the vessels and tracheïds of the xylem of the stele. By this means water with various salts and other constituents in extremely small quantity, is forced into the fibro-vascular tissue. The process is not a purely physical one of filtration under pressure, but is regulated to some extent by the protoplasm of the most internal cortical cells. When these are distended to their greatest capacity the protoplasm appears to be stimulated, perhaps by the very distension, and in consequence to allow water to transude through its substance. This mode of response to stimulation is not infrequent in vegetable tissues; indeed, it appears to correspond to the response of a muscle to stimulation by the process of contraction. The protoplasm thus relieves itself of the over-distension, and we get an intermittent pumping action set up, which has a certain rhythm. By it large quantities of liquid are continually being forced into the axial stele.

This water, under particular conditions, may accumulate in the vessels, and its presence can then very readily be demonstrated and the force of the root-pressure measured. If a vine stem be cut through in the early spring, before its leaves have unfolded, a continuous escape of water takes place from the cut surface, and the vine is said to *bleed*. This phenomenon is not peculiar to the vine, but is shared in by all other terrestrial plants. In many herbaceous forms this forcing out of water by root-pressure may be seen without cutting the plant at all. Many grasses and other herbaceous plants show in the early morning a certain exudation of water from the tips of their leaves, which is due to the same over-turgescence.

To measure the root-pressure in a plant the apparatus shown in *fig.* 1184 may be used. It consists of a T-piece of glass tubing which is fastened by indiarubber rings to the top of a cut stem, such as that of Helianthus. To the side arm of the tube a bent tube of capillary bore is attached by a tightly fitting cork, and the T-piece is filled with water. Mercury is poured into the bent tube till it stands at a level a little below the cork. As the root continues to take up water it forces it into the tube R, whence it overflows into the capillary tube, causing the mercury in its two limbs to be at unequal levels. By the displacement of the mercury the force of the root-pressure can be estimated.

The root-pressure of various plants has been measured by

different observers; an idea of its amount may be gathered from the fact that a medium-sized Fuchsia in a pot has been found able to send a column of water up a tube of the same diameter as its stem to a height of twenty-five feet.

This force is continually at work while the transmission of water is going on, but it is not easily seen later in the year. If the stem of the vine be cut in July instead of April, no bleeding follows the wound. This is not, however, due to the absence of activity by the roots, but to the fact that a copious evaporation is taking place from the leaves. In the experiment in April the conditions were different, there were no expanded leaves, and the water absorbed and sent upwards by the root consequently accumulated in the vessels of the stem, escaping at once when the latter was cut; in July the vessels had been emptied by the transpiration, and there was no accumulation of water there to overflow. The apparatus just described will show, however, that the root-pressure is still at work if it be used in July.

FIG. 1184.

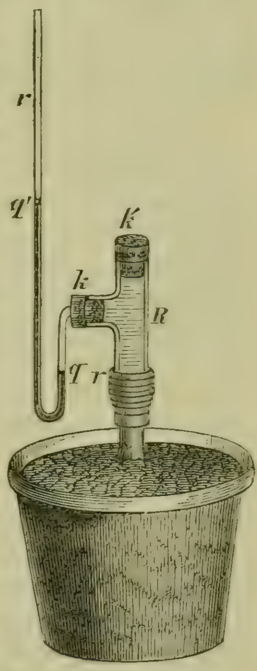


Fig. 1184. Apparatus for the estimation of root-pressure. (After Sachs.)

The root-pressure, though always considerable, is not constant in amount; it is lowest in the early morning, when it begins to increase; it continues to rise till about midday or a little later, then gradually sinks. A second rise takes place towards evening, and then it sinks continuously all night. The causes of this rhythmic daily period are at present unknown; it does not appear to depend upon variations of its surroundings, but to arise from some cause inherent in the constitution of the plant.

TRANSPIRATION.—The modified evaporation taking place from the surfaces of the succulent parts of plants, and regulated in amount by the protoplasm of the cells, is known as transpiration. It is easy to demonstrate the fact of its continuous existence by enclosing a plant, or part of one, in a dry glass vessel, which can be closed so as to admit no air. Very soon the surface of the glass is covered by a fine dew, which is the condensed vapour escaping from the plant. The same thing

may be seen if a vigorous plant be covered over by a bell-jar, the water condensing copiously upon the sides of the latter.

The evaporation takes place to a certain extent through all the epidermal cells of the transpiring organ, but not to a very great one, the degree of development of the cuticle having considerable influence upon the amount. It is carried out much more freely through the thin walls of the cells abutting upon the intercellular spaces, which, as we have seen, communicate with the external air by means of the stomata and the lenticels. The transpiration is most copious in the leaf, the structure of the lower side of which, in dorsiventral leaves, is especially favourable to it. If a leaf be taken which has stomata upon its under side only, and the rate of transpiration from its two surfaces be compared, it will be found that the stomatal gives off considerably more vapour than the other surface.

The amount of moisture given off in transpiration varies in different plants. In the sunflower (*Helianthus*) the amount has been stated to be $\frac{1}{163}$ cubic inch of water per square inch of surface in twelve hours. Doubtless individual plants show a considerable variety, however, in the amount. This copious evaporation readily explains why bleeding of plants from wounds cannot be observed when the leaves are expanded and active.

The removal of the water accumulated by root-pressure in the closed system of vessels leads to a diminution of the pressure of the air they contain, so that while transpiration is active there is a negative gaseous pressure existing in them. This is of considerable importance in assisting in the movements of gases in the plant, and it further helps the pumping action of the root in pressing forward the water by exerting a suction upon the parenchymatous cortex.

Transpiration is not a process of simple evaporation. As in the other phenomena we have examined, the protoplasm exercises a regulating influence upon the escape of watery vapour from the cell. If the amount given off from a measured area of leaf surface be compared with the amount evaporated from an equal area of free water, the latter is found to be much the greater. That this is due to the life of the leaf, and therefore to the protoplasm, is seen from the fact that a dead leaf gives off its water and dries up more rapidly than a surface of freely exposed water. The cuticle of the living leaf and its cell-walls are consequently not the causes of the differences observed.

If the protoplasm of the cells of the turgid leaves of a branch be stimulated by violently shaking it, the leaves become flaccid.

The protoplasm under the stimulus allows more vapour to pass through it, as that of the cortex of the root permitted water to pass out of its cells under the stimulus of over-turgescence.

The ultimate exudation of watery vapour is thus seen to be chiefly carried out through the stomata of the green parts, at any rate in those plants which possess them. The mechanism of the stomata has already been alluded to. The guard-cells which surround the aperture are capable of varying turgescence, the water entering and leaving them from the other cells of the epidermis, which abut upon them. Those walls of the guard-cells, which abut upon the air space underlying them, are, as a rule, thickened and cuticularised (*fig.* 1185), so that vapour cannot enter them. The wall between them and the next epidermal cell is thin and readily allows of osmosis. The guard-cells themselves differ from the rest of the epidermis in the higher plants by containing chloroplasts, which suggests the presence in them of more osmotic substances than the other epidermal cells contain. The guard-cells are so attached to each other that turgescence causes them to separate, opening the aperture. Loss of water induces in them a flaccid condition, and their edges fall together and partly or wholly close the slit. Hence, when the cells of the epidermis are turgid, the stomata open; when they lose their turgescence these organs are closed. Thus the escape of watery vapour is accelerated or retarded by their action.

FIG. 1185.

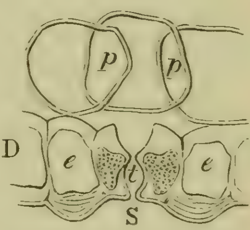


Fig. 1185. Stoma of Hyacinth leaf. *e*. Epidermal cells. *t*. Opening of the stoma. *p*. Parenchyma of the leaf.

Transpiration is markedly increased by light, rising to many times its original amount when a plant is transported from darkness into sunshine. This is not due to the rise of temperature accompanying the illumination, though the greater warmth may have some influence upon it. The effect of light upon the stomata is to cause them to open; hence they are open during the day and closed during the night. It is probable, however, that this is not directly due to the light. If coloured light be employed, it is found that the rays which influence the opening or closing are those which are absorbed by chlorophyll—a fact which has some significance when it is remembered that the guard-cells contain that pigment.

Other external conditions which have an influence upon this

function are the hygrometric condition of the air, the temperature of the soil in which the roots of the plant are embedded, and the mechanical disturbances to which the plant is subjected. If the air be dry, transpiration is vigorous; if moist, then it is checked. If a plant be exposed to a warm, dry atmosphere till the leaves droop from too great a loss of water and then be transferred to one saturated with moisture, after a short time they again become turgid. This is not due to an absorption of water in the form of vapour by the leaves, but to a diminished loss by the checking of transpiration. The return of turgidity is caused by the accumulation of the store drawn from the earth by the roots. Warming the soil increases the amount of vapour given off by the leaves. The mechanical disturbance of shaking has already been alluded to, and it has been seen that when thus stimulated, the protoplasm allows transpiration to increase. This helps to explain the flaccid condition observable in some trees after the prevalence of a high wind. The continued renewal of the air around the transpiring organs may also have the effect of increasing the removal of vapour.

When transpiration is excessive, the leaves and branches lose their turgescence, become flaccid and droop. A branch which has reached this condition may be revived by forcing water into it, which can be done by fastening it in one arm of a U-tube containing water and pouring mercury into the other. The restoration of the water restores the turgidity of the tissues.

Transpiration is of the greatest importance to the plant in many ways. By maintaining a copious flow of liquid to the cells of the leaves, it brings to the metabolic cells of their mesophyll a supply of the materials needed by the plant for the construction of its nutritive substances, and it assists in the transportation of the stored material laid up in various parts of the stem and root to the growing parts and other seats of consumption. Its influence in maintaining the turgidity of the tissues is also very considerable, and this turgescence is of the highest importance to the growing cells, growth itself and many adaptations to changes in the plant's environment being dependent upon it. The negative gaseous pressure in the vessels, already alluded to, is dependent upon transpiration. The importance of the presence of the water to the life of the protoplasm has already been shown.

CHAPTER V.

THE FOOD OF PLANTS. INTRODUCTORY.

A GOOD deal of misconception exists as to the nature of the food of plants. The character of their environment and the absence of any means provided in their structure for taking in material of a nature in any way approaching the composition of living substance, has led to a not unnatural idea that they feed upon simple inorganic compounds of comparatively very great simplicity. The idea has found considerable support in the fact, which is easily ascertained, that such bodies are those which are absorbed in the first instance. By their roots when they live fastened in the soil, or by their general surface when they are inhabitants of water, comparatively simple inorganic salts are found to enter them with the water that they take up. By their green parts, and especially by their leaves, carbon dioxide is absorbed, either from air or water, according to their habit. A study of the whole vegetable kingdom, however, throws considerable doubt upon the theory that these substances are, in the strict sense, to be called their food. Fungi and phanerogamic parasites can make no use of such bodies as CO_2, but draw elaborated products from the bodies of their hosts. Those fungi which are saprophytic, in the same way can only live when furnished with organic compounds of some complexity, which they derive from decaying animal or vegetable matter. We have no reason to suppose that the living substance of these non-chlorophyllaceous plants is so radically different from that of their green relations that it has a totally distinct mode of nutrition.

In the higher plants we find a stage of their life in which the nutritive processes approximate very closely to those of the group last mentioned. When the young sporophyte first begins its independent life—when, that is, it exists in the form of the embryo in the seed—its living substance has no power to utilise the simple inorganic bodies spoken of. The shoot which a potato puts out derives its food from the interior of the tuber. Fleshy roots, corms, bulbs, and all bodies which are capable of renewed life after a period of quiescence, show us the same thing; the young shoot emerging from any of them is not fed upon simple inorganic bodies, but upon substances of considerable complexity, which it derives from the tissues of the structure from which it springs.

Even in adult plants of the most considerable complexity we find instances of the same thing; the living substance is nourished by materials which have been constructed by it and stored at various places in its substance till their consumption has been called for.

What, then, are these substances which, in the strict sense, constitute the food of plants? We can ascertain what are necessary by inquiring what are the materials which are deposited in the seed for the nutrition of the embryo when the seed germinates. We find there examples of great classes of food stuffs which are similar to those on which animal protoplasm is supported, and are led again and again to the idea that vegetable protoplasm is essentially identical with the latter. Proteids, carbohydrates, fats or oils are the materials which, in varied forms, are met with. If we study the protoplasm of a living active vegetable cell and treat it with appropriate solvents, we can extract representatives of these, or of some of them, from its substance, the meshes of which are the places in which it is deposited. The nutrition of the protoplasm can only take place when these substances are brought into the most intimate relations with it; from them, no doubt, in ways not yet discovered, it builds itself up, and by its own decomposition it reproduces them. The interchange of matter between the living substance and its food, the way in which the latter is transformed into the former, are points about which yet almost everything essential remains to be discovered.

But while we recognise that the ultimate nutrition of protoplasm is dependent upon a supply to it of such materials, we are face to face with the fact that such materials are not furnished from the environment to the ordinary green plant. On the other hand we find the latter taking in by ordinary physical processes CO_2 from the air and a variety of salts from the soil, and we ascertain that if these are supplied under suitable conditions, the plant can flourish and develop. In one sense, then, these substances constitute its food, but we must carefully consider what we mean by the term. In the nutrition of such plants there are clearly two very different processes combined, which should be kept carefully distinct. We have the absorption of *food materials* rather than of food in the true sense, and we have, following such absorption, the expenditure of a considerable amount of energy upon these food materials, with the result that they are worked up into the complex compounds which we find protoplasm can assimilate, and which are those

which are stored away in the substance of the plant for the nutrition of embryo, bud, or growing point.

This may be made clearer by examining whether these simple inorganic materials are capable of nourishing protoplasm when freely supplied to it. If they are the true food, plants everywhere should be able to make use of them. But if we consider only one of them, the CO_2 of the air, we find this is not the case. The plants which are not green, that is, which contain no chloroplasts, can do nothing with this gas. So long as a seed is in the early stages of its germination it is surrounded by CO_2 which is given off by its own protoplasm. But it can make no use of it, and if the store of nourishment provided for it in the endosperm or cotyledons is cut off, it inevitably dies of starvation.

If a green plant, which is in good health and endowed with ample vigour, is removed from light to darkness, though CO_2 be supplied in appropriate quantity, it can make no use of it.

So with other constituents of the materials from which the true food of the living substance is elaborated. They are absorbed in quantity, but they are not food until a considerable amount of work has been done upon them by the plant itself.

In connection with the nutrition of plants we have thus to deal with the absorption of the crude food materials and to study the changes which they undergo after such absorption. But this is not all; the food which is laid up in seeds, tubers, bulbs, &c., is not deposited there in exactly the condition in which the living substance requires it, so that there remains for us to consider the processes which these materials also undergo for the purpose of feeding the living protoplasm. The first process is one of building up complex bodies from simple materials; the second is comparable with the *digestion* which is so marked a feature of animal alimentation, and is one of breaking down very complex bodies into simpler ones. The nutrition of the protoplasm shows two similar phases; the absorption of the ultimate constituents of the food, or its *assimilation*, is a constructive process; it is in turn associated with a destructive one, by which, from the protoplasm itself and by its own activity, simpler bodies are produced. The whole round of changes which embraces all these operations is called *metabolism*, the constructive processes being grouped together under the name of *anabolism*, the destructive ones under that of *catabolism*.

The absence of well-differentiated organs set apart for the

discharge of these functions makes it rather difficult at first to appreciate their independence. In the animal body such a differentiation is easily seen, but in plants the cellular structure is so prominent, and the life of the protoplasm is so closely related to its condition in the cell, that attention needs to be specially directed to the point. Each protoplast is dependent upon the contents of its own vacuole, and the early constructive processes in the metabolism may take place in it side by side with the digestive ones and at almost the same time. True, a certain division of labour can be noted, but it is not very clearly associated with particular structures. Thus the leaf is especially concerned in the processes of anabolism, but it is mainly so by virtue of the chloroplasts which its cells contain. These processes can go on perfectly well in other parts than leaves; indeed, wherever there are chloroplasts we know they do. Thus, though we associate the leaf with anabolism, it would be wrong to say that it is the organ to which this process is referred. We can say with greater accuracy that the *chloroplast* is the organ conducting these preliminary anabolic processes, and that they take place wherever the chloroplasts are found. Their wide distribution, however, shows us that there is not a specially differentiated member of the plant set apart to be an organ for this function. In the same way, a catabolic process, the digestion of stored products, goes on wherever there are reservoirs of such bodies, and there, and there only, unorganised ferments or enzymes are found, instead of being located in particular glands, as in the animal body. These reservoirs, we have already seen, and shall see again later, are found in the most varied regions of the plant's substance—regions, moreover, which vary considerably in different plants.

Starting, then, with the intricacy of the metabolic processes placed before us, and with their relations to each other, we may begin the consideration of them in detail with an inquiry into the introductory absorption of the materials from which the food is ultimately made. Even here we meet with some complexity, as the ordinary green plant shows marked differences in behaviour from its parasitic relation, and from the great class of fungi, which possess no chlorophyll. It will be best to consider first the ordinary terrestrial green plant, noticing in passing differences in behaviour shown by aquatic and epiphytic forms.

CHAPTER VI.

THE ABSORPTION OF FOOD MATERIALS BY A GREEN PLANT.

We have seen that the materials which protoplasm is eventually able to assimilate, and which, therefore, constitute its food, are of a similar nature to those deposited in seeds and other storehouses of nutriment which are variously disposed in its substance. We know, further, that these are not the materials which an ordinary green plant takes into itself from the environment in which it lives. On the contrary, we know that its structure prevents its taking in anything solid, but that it is continually absorbing liquid by means of its roots. Between the raw materials that can be so absorbed and the complex products which are needful for the nutrition of its substance there is a great difference, and the manufacture of these latter from the raw materials taken in constitutes a very important part of the metabolic processes.

To ascertain what this work of construction consists of, we must find out what elements the substance of the plant and the true nutritive matter contain, how these are supplied to the plant, and what work is done upon them in its cells.

As already noticed, the structure of the plant demands that all the materials of a solid character shall be in such a form of solution that they can enter its substance by means of the physical process of osmosis, modified as we have described. This is equally true of gases, of which there is considerable absorption by all plants, whatever be the nature of their habitat.

The details of absorption vary to some extent, however, according to the environment of the plant. Aquatic plants can absorb water and whatever is dissolved in it, whether of gaseous or solid character, by all parts of their surface. Those which grow with their roots embedded in soil and their shoots exposed to the air show a certain division of labour in this respect. The mineral constituents obtained from the soil are taken in by the roots with the stream of water; those of a gaseous nature mainly find entry through the leaves and other green parts.

If we examine the food stuffs described as being essential, we find that proteids contain carbon, hydrogen, oxygen, nitrogen, sulphur, and perhaps phosphorus. Carbohydrates and fats contain only the first three of these elements. A destructive analysis of the plant, made by burning it, shows that it contains others also; for after all the volatile products of combustion have been

driven off, a certain inorganic residue is left, which is composed of several metals and some other elements. An analysis of this residue, which is spoken of as the *ash*, will not, however, tell us in what condition these different constituents exist in the living plant, on account of the various chemical changes which go on during the combustion.

The ash of plants is found, when analysed, to contain always the four metals—potassium, magnesium, calcium, and iron. These are not present in the metallic condition, but in combination with various acids, forming nitrates, sulphates, chlorides, carbonates, phosphates, &c.

Besides these, various plants may individually contain greater or less quantities of many other elements variously combined. We find sodium very generally present; less frequently so aluminium, copper, zinc, manganese, silicon, bromine, iodine, and others. Indeed, the composition of the soil in which a plant grows determines to a very great extent what minerals enter it. If a substance is soluble in the liquid which the root-hairs absorb, a certain quantity will, by ordinary physical processes, be taken up by them.

The quantity of each substance a given plant will absorb will depend upon whether the plant makes use of it in any way. If so, it will be quickly removed from the absorbing cell and more will enter. If not, the cell-sap of the absorbing root-hair will soon have taken up as much of it as it can contain, and the absorption of that particular substance will cease.

Some of the materials found in the soil are readily soluble in the water which the soil contains. Such can enter the plant without difficulty. Others are soluble only in water containing CO_2, and as considerable quantities of this gas are continually being generated in the soil, the water there is charged with it, and bodies, otherwise intractable, are thereby brought into solution and absorbed. A third factor in the process of absorption is the acid sap which the root-hairs contain. Not only does this acid cause water to enter osmotically, but a little of it exudes in the same way, and this has a certain solvent action upon the particles to which the root-hairs cling. Thus certain salts can be absorbed, though soluble neither in pure water nor in water containing CO_2.

The solutions taken in are excessively dilute. There is, however, a certain relation necessary between the substance and the water, for we have already noticed that strong solutions cannot pass the lining layer of protoplasm. Every salt is taken

up in a certain strength of solution, or, in other words, with each molecule of salt there is a certain invariable quantity of water absorbed. The quantity is not the same, however, for each salt.

The salts which different plants absorb, in like manner vary as to amount. If two different species are growing in the same soil, side by side, under exactly the same conditions, the amounts of the several salts present in the soil which are absorbed by the two plants will not be the same. In each case the quantity will vary according to the use which the plant can make of it.

Conversely, if the same soil contains several different salts, a plant will not absorb them in equal proportions, nor in those in which they exist in the soil. This fact admits of a similar explanation. Again, the absorption of a salt will cease as soon as the cell-sap contains the same amount of it as the fluid outside the root-hair. In this case there will be no osmotic action so far as the salt is concerned, though there may be a continuous amount of water entering the hair.

We have seen that the continuous absorption of water by the root-hair will depend upon certain external conditions, such as the temperature of the soil, the activity of transpiration at the time, &c. These conditions affect also the absorption of the substances in solution.

The substances which are absorbed in this way by the roots are naturally very varied. The most important of them in the metabolism of the plant are the compounds of nitrogen. In the soil these exist in the form of nitrates or nitrites of the metals mentioned, and as compounds of ammonia. Green plants take in little or none of the latter, which are, however, made available for their use by the action of certain bacteria which the soil contains, which have the power of converting the ammonia compounds into nitrites and the latter into nitrates, in which form they are taken up. This process of *nitrification* is the special property of two of these organisms, one of which forms nitrites from the ammonia compound, and the other forms nitrates from nitrites.

It is in this way that a normal green plant absorbs all the nitrogen which it uses for the construction of food substances. The nitrogen of the air is made use only of in very exceptional cases. Certain lowly Algæ seem to have the power of using it, but the process is not fully understood. A few plants belonging to the Leguminosæ can also use atmospheric nitrogen, but their power depends upon the association with their roots of certain

fungi which infest the cortical tissues and develop peculiar tubercular structures upon the roots. The actual mode of absorption in this case also is obscure; the parts played by the root and the fungus respectively are not at all determined.

The water taken up is the main source of the hydrogen and oxygen which are used in the anabolic processes. A little of both these gases is taken in in the several combinations of the metals; sulphates and phosphates contain both, nitrates and carbonates contain oxygen. The amount of them absorbed in these forms is, however, relatively small. The other elements mentioned enter the plant in various combinations in the water stream.

The gases present in solution in the water of the soil also make their way into the root-hairs with the stream, but the quantity is very slight compared with what is absorbed by the aerial parts. The gas CO_2, which we have seen to be present in the earth in considerable amount, is, however, not made use of in the anabolic processes. All of this particular food material is taken in from the air. A little carbon is absorbed in the form of carbonates. More complex organic compounds of carbon are taken in by those roots with which fungi are living symbiotically, such as the mycorhiza of some trees, but this is exceptional.

The absorption of gases from the air takes place in the leaves and other green parts. They enter freely through the stomata and find their way thus into the intercellular spaces, which are very numerous. These intercellular spaces contain a mixture of gases which, though approximating to the composition of atmospheric air, yet differs from it in the relative quantities of the constituents. This can be readily understood from the consideration that considerable gaseous interchange goes on in these spaces between the air they contain and the living cells which abut upon the spaces. The cell-walls here are very delicate and thin, and are saturated with water. In this water the different gases present dissolve according to their degree of solubility. The quantity of each taken up depends, as in the case of the metallic salts just discussed, upon the ability of the cells to make use of the gas. If it can be combined in any way with other bodies in the cell, it is withdrawn thus from the sap and room made for more to enter. If not, the limit of saturation of the sap is soon reached.

Probably little or no absorption of gas takes place through the cells of the epidermis, though they are freely in contact with the air. Sections show us that they are provided usually with a

cuticle, which resists any such solution as is necessary for absorption.

The only gas which is absorbed as a food material from the air is carbon dioxide, CO_2. This exists to a very slight extent in the atmosphere, only about four parts in ten thousand being normally present. The very large green surface which an ordinary terrestrial plant possesses renders, however, a considerable amount of absorption possible. If the general conditions are favourable, the absorption is continuous, for CO_2 is at once decomposed in the cells of the green tissue, and so a stream is always entering.

Both nitrogen and oxygen are soluble in water, though to a different extent. It has been already stated that the nitrogen so taken in is not used in the constructive processes, and accordingly but little is absorbed in this way. The oxygen which enters is larger in amount; experiments have proved, however, that it is not a food material, but is used for other purposes.

The absorption of CO_2 takes place usually at the ordinary atmospheric pressure or at one a little greater. Plants can, however, absorb this gas when it is present in much larger proportion than it is in air. Too much is, however, possible, and then the cells are unable to take it in at all. The absorption of CO_2 is possible only under certain conditions; the cells which contain chloroplasts are the only ones which can take it in in any quantity, and they only when they are exposed to sunlight, preferably a bright light, and when the plant is maintained at an appropriate temperature. Its absorption is accompanied by the evolution of a volume of oxygen, which is equal to the volume of CO_2 absorbed, and it is attended by a continuous increase in the weight of the plant.

We have seen that the water absorbed by the roots is transported regularly through the axis of the plant until it reaches the leaves, in which after traversing the cells of the mesophyll it is evaporated into the intercellular spaces. Into these cells of the interior of the leaf all the food materials are thus at once transported, both those entering from the soil and those absorbed from the air. These mesophyll cells have generally a different arrangement on the two sides of the leaf, but they all agree in containing chloroplasts. In these cells takes place the work of construction of organic substance, such as the plant can live upon, work which is carried out mainly through the instrumentality of the chloroplasts.

As already noticed, various elements are constantly found in

plants which do not enter into the composition of the actual nutritive substances. The part that many of them play is obscure; indeed some of them, as sodium, seem to be quite useless. Some play a secondary part in protecting the plant tissues in various ways from destructive influences, some enter possibly only as the medium by which the combined nitrogen, sulphur, and phosphorus are absorbed. Others, especially potassium, calcium, magnesium, and iron, have a part to play in enabling the more important elements to be worked up into nutritive material.

In the cases of some green plants these processes of absorption are supplemented by others. In several Natural Orders there are species which are semi-parasitic in their mode of life. Though they possess leaves, stems, and roots, they do not live entirely at their own expense, but certain of their roots penetrate the tissues of the roots of other plants near which they grow. The degree of this *root-parasitism* varies a good deal in the different groups. These plants supplement the processes we have just described by drawing elaborated food material from the host which they have attacked.

The pitcher plants, *Nepenthes*, *Sarracenia*, &c., and the fly-catching plants, *Drosera*, *Dionæa*, and others, can also absorb nitrogenous material by the special mechanisms which they possess. In the pitchers of Nepenthes, &c., there is an accumulation of water in which insects are from time to time drowned. Their bodies decay or are digested, and the products of the decomposition are absorbed by the tissue of the pitchers. The flies and other insects captured by Drosera and its allies are similarly disposed of.

CHAPTER VII.

THE CHLOROPLASTIDS AND THEIR FUNCTION.

We have seen that the different materials out of which the food of the plant is constructed are carried by various means to the cells of the parenchyma of the mesophyll in which chloroplastids are present. The chloroplastid is a small differentiated body consisting of protoplasm in the meshes of whose substance a green colouring matter, *chlorophyll*, is contained in some form of solution. Alcohol, chloroform, ether, benzol, and other liquids can dissolve the chlorophyll and leave the plastid colourless.

Chlorophyll is not soluble in water, nor can it be extracted with acids or alkalies without alteration.

A solution of chlorophyll in any of the liquids mentioned shows the curious property of *fluorescence*; if regarded by transmitted light it appears green, but if a strong solution is looked at by reflected light it has a blood-red coloration.

If a solution of chlorophyll is placed in the path of a beam of light which is then allowed to fall upon a prism, the resulting spectrum is found to be modified. Instead of showing a continuous band in which all the colours are represented, it is interrupted by seven vertical dark spaces. The rays which in the absence of the solution of chlorophyll would have occupied those spaces have no power to pass through it, or, in other words, chlorophyll absorbs those particular rays of light which are missing.

In *fig.* 1186 is a representation of the spectrum, called from the facts just narrated the *absorption* spectrum. The first band on the left is the darkest, and is found to be in the red part of the spectrum. The three bands on the right are broader, but not so well defined. They cover nearly all the blue end. The three thinner and lighter bands are in the green and yellow parts of the spectrum. Chlorophyll therefore has the power of absorbing a large amount of red rays, a good many blue and violet ones, and a few of the green and yellow. The distinctness with which the absorbtion bands are seen will depend upon the strength of the solution, the red and blue being, however, always prominent.

Careful chemical experiments have proved that chlorophyll is a single pigment, and not a mixture of two as has often been stated. It is, however, very easily decomposed, and the products of its decomposition are generally found with it in the chloroplastid. One of these, *Xanthophyll*, which is of a bright yellow colour, is always extracted with the chlorophyll by alcohol. It can be separated by appropriate treatment.

Chlorophyll is formed in the chloroplastids only when they are exposed to light, except in one or two rare cases. When a plant is grown from a seed or a tuber in the dark, the resulting stem and leaves are not green, but of a peculiar yellowish-white appearance. Nor can it be developed in the absence of a suitable temperature. Its formation has been found to depend upon the presence of iron in the plant, but the exact relation of the iron to the pigment is not known; it does not appear to enter into the composition of the latter.

The construction of organic substance proceeds in the cells of the mesophyll containing the chloroplastids and supplied with the raw materials in the way described in the last chapter. It can, however, take place only under the influence of light, and while the cells are at an adequate temperature. The complex products of the anabolic process are at first mainly, if not entirely, confined to two classes, carbohydrates, and some nitrogen-containing compound, probably proteid. Many other forms of organic substance appear in plants, such as fats or oils, gluco-

FIG. 1186.

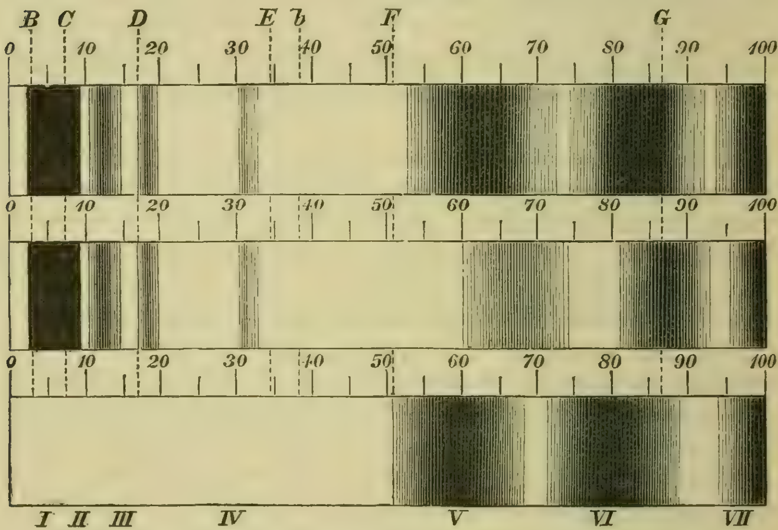


Fig. 1186. Absorption spectra of chlorophyll and xanthophyll. (After Kraus.) The upper spectrum is given by an alcoholic extract of leaves, the middle one by dissolving chlorophyll in benzol, and the lowest by xanthophyll. The bands in the least refrangible portion, B–E, are figured as obtained with a concentrated solution; those in the most refrangible part of the spectrum, F–G, are given as obtained with a weak solution. The letters B–G indicate the principal rays, the numbers I–VII the absorption bands of chlorophyll from red to violet, and the figures 0–100 divide the length of the spectrum into 100 equal parts. (After Sachs.)

sides, &c., but these are probably all produced by processes of catabolism, and are not directly constructed from the simple bodies absorbed.

We will examine first the process of formation of carbohydrates. These consist of the elements carbon, hydrogen, and oxygen, the latter two existing in the combination in the same proportion as they do in water. The source of the carbon and the oxygen is the CO_2 absorbed from the air, while the hydrogen is derived from the water of the cell-sap.

When carbon dioxide is exposed to the influence of the chloroplastid in the presence of light and moderate warmth, it undergoes a decomposition which may probably be expressed by the equation $2CO_2 = 2CO + O_2$, splitting up into carbon monoxide and oxygen. At the same time, water is decomposed, probably in the way denoted by the equation $2H_2O = 2H_2 + O_2$. The two molecules of oxygen unite and are evolved, the quantity being the same as the quantity of CO_2 undergoing decomposition. The two residues, 2CO and $2H_2$, are then thought to unite to form $2CH_2O$, a body known as formic aldehyde. It is a property of the aldehydes to undergo readily what is known as *polymerisation* or condensation of several molecules together. Such a condensation of formic aldehyde would lead to the formation of sugar thus,—$6CH_2O = C_6H_{12}O_6$; and it is probable that this process takes place. At any rate, sugar is present in the mesophyll cells very speedily after the absorption of the CO_2 and the beginning of the exhalation of oxygen.

These processes are carried out by the chloroplastid under the conditions set forth. It is evident that such changes as the decomposition of CO_2 and water cannot be accomplished without a good deal of energy being expended upon them. In this need we have the explanation of the composite nature of the plastid. The chlorophyll absorbs certain of the rays of light that fall upon it, and the energy so acquired is applied by the protoplasm of the plastid to effect the decompositions that take place. Sugar is the result, though what kind of sugar is first formed is still open to experiment. There is a fairly copious and continuous production of it, indicating, as in the case of the raw materials and the cells which absorb them, that there must be a removal of it as it is formed. Otherwise the cell-sap would be saturated with sugar and its formation would cease. The quantity which is in excess of the immediate needs of the cell may either be transported away from it by diffusion, or some of it may be converted into an insoluble form and be temporarily deposited in the cell. The latter operation is carried out by the plastid, which quickly forms small granules of starch in its own substance, at the expense of some of this surplus sugar. The starch can readily be detected *in situ* by treating the leaf with iodine, after bleaching it by soaking it in alcohol. This appearance of starch was formerly held to be the last stage in the ordinary anabolic processes, but as starch must be re-converted into sugar before protoplasm can use it as food, its occurrence is now held to be a case of what we shall see is a very usual thing in plants,

the accumulation of food material in various parts, to be there held in reserve till the plant requires them.

It is not certain that the process of construction of carbohydrate is so simple as what has been said would imply. There are many other chemical compounds in the cell while it is proceeding, and to what extent they take part in the matter is not known. It is held that some compound of potassium, at any rate, is concerned in the process, for in the absence of this metal sugar does not appear to be formed.

The formation of the proteid bodies in the cells is not at all well understood; indeed, but little is known certainly about it. The nitrates are absorbed and taken to the mesophyll cells. In these cells and in others about the plant, bodies occur of comparatively simple composition, though much more complex than nitrates. These, which are known as *amides*, include asparagin, leucin, and several others. Probably they are the first bodies constructed from the nitrates, though in many cases they arise from the decomposition of proteid and not from anabolic processes. It is in the form of these bodies generally that organic nitrogenous matter travels about the plant. From them most likely proteid is constructed, compounds of sulphur and of phosphorus in the cells supplying those elements, which, as we have seen, are probably both in the molecule of proteid. Certainly sulphur enters into its composition.

Again there is reason to think that the carbohydrate manufacture is associated with the nitrogenous one. Proteid can apparently only be formed under the same conditions as carbohydrate, though we cannot say that chlorophyll is directly concerned. If a shoot is not exposed to light, there will be an accumulation of asparagin in its tissues; the same thing will be observed if CO_2 is excluded from access to it. Indeed, if carbon assimilation is prevented, nitrogenous material cannot be formed.

The proteids, if formed in the leaves, as is probably the case, are affected just as we have seen the carbohydrates to be. They undergo a partial decomposition, and their nitrogenous residues leave the cells in the form of amides. Their further fate will be examined later.

The proteid, which is the most complex body known to exist in the plant with the exception of the living substance itself, cannot at present be represented by any chemical formula. Analyses of the purest forms of it point to its percentage composition lying within the following limits:—

Carbon	50·0	to	55·0
Oxygen	22·8	,,	24·1
Nitrogen	15·0		18·2
Hydrogen	6·8	,,	7·3
Sulphur	0·4	,,	0·5

There are several classes of these bodies known, the differences which they show depending chiefly on their solubilities in different liquids. The best known groups are the following:—

1. Albumins. These are soluble in distilled water, and if the solution be heated the proteid is converted into a peculiarly insoluble form, known as *coagulated* proteid, and deposited. Albumins can be precipitated unchanged by saturating their solutions with sodio-magnesic sulphate. Their coagulation temperature ranges from 70° to 80° C. They are not of common occurrence in plants, but may be extracted from certain roots.
2. Globulins. These differ from albumins in not being soluble in distilled water. They can be dissolved by adding a little neutral salt, such as sodium chloride. Their solutions are coagulated on heating, and they can be precipitated by saturating them with magnesic sulphate. There are many members of this class, which differ from each other by varying solubility in different strengths of the salt solution. Their coagulation temperatures vary a good deal, some being changed at about 55° C. and others not till about 75°—80° C.

   The proteids found in plants chiefly belong to this group. They can readily be extracted from most seeds. Probably this form is the one which occurs in the mesophyll cells.
3. Albuminates, or derived albumins. These are soluble in weak acids and alkalies, but their solutions do not coagulate on boiling. They can be precipitated by carefully neutralising the solution.
4. Albumoses. These are soluble in water, and do not coagulate on heating. Their characteristic reaction is that they give with nitric acid a precipitate which dissolves on warming the liquid, and reappears as it cools.
5. Peptones. These are much like albumoses, but do not give a precipitate with nitric acid.

The members of the last two groups are capable of dialysing through membranes, which those of the first three cannot do.

The peptones dialyse with far greater ease than the albumoses. They do not occur very plentifully in plants, and are probably formed in them only from the decomposition of the more stable forms of globulin and albumin. Some of the albumoses occur in certain seeds in association with some of the globulins.

By the action of peculiar secretions of the protoplasm, belonging to the bodies known as *enzymes* or *unorganised ferments*, the globulins and albumins can be decomposed, with formation successively of albumoses, peptones, and amides such as asparagin and leucin.

It has been considered by some botanists that the sieve-tubes or their companion cells are the places where the construction of proteid is completed, only the amides being formed in the leaves. It is, however, possible that this construction is, like that of the deposition of starch in the chloroplastid, rather the expression of the temporary deposit of proteid in those cells at the expense of the surplus formation, which, not being needed in the cells of the mesophyll, is converted into amides and so transported from the leaf. A certain amount of proteid can be extracted from the living cells which are the seat of the original anabolic processes.

The importance of the inorganic salts which do not enter into the composition of the living plant-substance is very imperfectly understood. Potassium is apparently necessary for the construction of carbohydrate matter by the chloroplastids. It is generally absorbed in combination with sulphuric, nitric, and hydrochloric acids, and can be found in the plant in combination with organic acids such as tartaric, oxalic, and malic. It is generally found in quantity in places where starch and sugar are stored.

Calcium and magnesium are absorbed in similar combinations, but their function has not been ascertained. The former appears to be concerned in the transport of carbohydrates from place to place. Both are of service in neutralising such acids as oxalic, the presence of which in quantity is deleterious. We frequently find in cells, and in some cell-walls, crystals of oxalate of calcium.

The importance of iron has been pointed out in connection with the action of the chlorophyll.

Most of the other elements absorbed seem to be without effect on the metabolic processes.

CHAPTER VIII.

RESERVE MATERIALS, AND THEIR DEPOSITION.

WE have seen that the amount of food constructed in the mesophyll cells from the crude materials absorbed is often considerably in excess of their immediate need. A certain amount is, no doubt, used up at once by the living substance of each cell, the assimilation of the food being the culmination of the anabolic processes, as protoplasm is the most complex material existing in the plant. The remainder is otherwise disposed of; no doubt a certain quantity is always retained in the cell to supply the needs of the protoplasm when actual construction is intermitted. Evidence of the temporary accumulation of a local reserve store is afforded by the occurrence of the starch grains which the chloroplastid forms inside its own substance. A great deal of the manufactured organic matter is, however, constantly leaving the cells in which it is formed, and passing to other parts of the plant. Even the temporary accumulation of starch soon disappears; if a plant, which has been vigorously forming it in its chloroplastids during a summer's day, so that at evening there is a great amount deposited there, is examined early next morning, the leaves are found to be devoid of starch. This is not brought about by its having been used during the night, for if the path of removal is obliterated, as it may be by severing the petiole, the leaf is found as full as on the previous evening.

Evidently, then, the surplus food manufactured in the mesophyll is transferred from the seat of its elaboration to other parts of the plant. To bring about this removal of the starch and inferentially that of the proteids, a certain alteration of them must be effected, the mechanism of which will be discussed later. The starch is converted again into sugar, and possibly some of the sugar may be further changed, though, no doubt, sugar is the general form of the travelling carbohydrate. The sugar which has not been transformed into starch may travel as it is, or some modification of it, still a sugar, though of another description, may be formed. That sugar is readily removed from the leaf may be inferred from several considerations. We can find but little of it in the mesophyll of the leaf, though we know it is constantly being produced. We do find it, however, fairly easily in the bast of the fibro-vascular bundles of the leaf,

and if a leaf is cut off from the stem while construction is going on, it can very soon be detected in the mesophyll cells as well.

Proteids are probably gradually broken down into amides, such as asparagin, which, being a readily diffusible body, can pass through the cell-walls.

These elaborated materials, in their passage from the leaves, travel by the bast and not by the wood. The carbohydrates and the amides probably go by the parenchyma. The sieve-tubes differ from the latter in containing a quantity of proteid material, and it is at least possible that proteid as such may travel by them. If so, it is probably reconstructed in the sieve-tube from the amides, &c., which are being transported from the mesophyll. A certain amount of carbohydrate also may go this way.

That the stream of elaborated food is transported by tissues external to the wood appears clear from the fact that if an incision is made round a branch or trunk of a tree and a small ring be removed, extending inwards as far as the wood, the growing parts below the wound dwindle and die, while those which leave the axis above the incision become more luxuriant.

Even along the path of the stream we find the same tendency to temporary deposition which we noticed in the chloroplastids. If the progress of the stream is checked from any cause, we find a temporary accumulation of starch near the point of stoppage, which disappears when the flow again asserts itself.

The direction which the food substances take is dependent upon many circumstances. When growth is active in any part, whether an apical meristem or a cambium layer, the stream is directed towards such seat of consumption. This is due to a process of diffusion set up in consequence of the removal of constructive material from the stream by the growing cells, and the consequent weakening of the solution there. When there is more produced than is sufficient to supply an immediate demand, the surplus is deposited in some part or other of the plant, to supply future needs. There is thus continually going on during active life a storage of surplus food substances in places which we may call reservoirs of reserve materials. In some cases they are again very speedily removed, but in others they remain there for a considerable time.

The nature of these reservoirs is very varied. Seeds, tubers,

bulbs, corms, fleshy roots, and other similar structures are perhaps the most easily examined. In seeds the reserve materials are deposited for the support of the young embryo, which will need them at the onset of germination. Tubers will require them for the support of the young shoots to which they give rise. Fleshy roots have to support a vigorous outgrowth after the expiration of winter. In the axes of woody plants we find stores laid up in sheaths of cells, such as the endodermis or pericycle, or in the medullary rays existing in the secondary wood.

In these reservoirs the stored substances are deposited in an insoluble form, or at any rate in a shape which is not suitable for rapid transport. In most plants the reserve carbohydrates are stored in the form of starch grains, which generally differ from those in the chloroplastids by their larger size and apparent complexity of composition. They are formed at the expense of the sugar of transport, usually by special bodies known as *leucoplasts* from their white colour. These bodies are very much like chloroplasts, except that they contain no chlorophyll. The leucoplast appears to absorb the sugar and pour out starch from some part of its surface. Layer after layer is so excreted, till a recognisable starch grain is produced, which shows the manner of its growth by faint striation of its surface, the striæ showing the limits of the successive lamellæ laid down. In some cases the lamellæ are strictly concentric; in others, as in the potato, the end next the leucoplast gradually becomes broader and broader, so that the shape somewhat resembles that of an oyster-shell. *Fig.* 1187 shows a group of leucoplasts actively forming starch grains. *Fig.* 1188 shows the striations of the complete grain.

Some grains often found in the potato are not so simple in their structure. These are represented in *figs.* 1189 A and B. The former usually arise by two or more originating in the interior of the leucoplast; as they grow they become closely pressed together and constitute a compound grain. *Fig.* 1189 B. shows what is often called a semi-compound grain. In such a formation the leucoplast produces two grains on opposite sides, and as they increase they come into contact. The leucoplast is so reduced to a ring surrounding them at their point of union, and its continued activity then forms new layers surrounding the whole. The leucoplast is gradually used up in its activity and disappears, leaving the grains of starch free. Many variations of its behaviour have been noticed in different cases.

Besides this formation of large starch grains by leucoplasts

we have many cases in which the deposition of starch is effected by the protoplasm of the cell. Such grains are generally very small, and show no structure. Instances of their occurrence have been already given. They are generally seen in the interior of the plant in reservoirs which are only temporary.

Carbohydrate materials are deposited in other forms in many plants. The root of the beet (*Beta vulgaris*) contains large quantities of cane sugar, as do the stems of the sugar-cane. The bulb-leaves of the onion abound in grape sugar. Many fruits contain different kinds of sugar. Inulin is stored in the tubers and tuberous or fleshy roots of many of the *Compositæ*. Glycogen occurs in the hyphæ of many of the Fungi.

FIG. 1187.

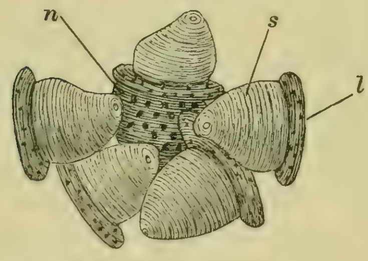


FIG. 1188.

FIG. 1189.

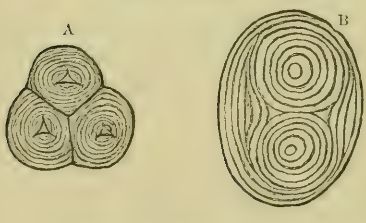


Fig. 1187. Group of rod-like leucoplastids, *l*, each bearing a starch-grain, *s*, collected round the nucleus, *n*, of a cell of the pseudobulb of an Orchid (*Phajus grandifolius*). × 500. (After Schimper.) —— *Fig.* 1188. Potato-starch (× 250). —— *Fig.* 1189. A. Compound; B. Semi-compound granule of starch.

In many Palms the carbohydrate is stored in the shape of cellulose, the walls of the endosperm of the seeds being enormously thickened. The cellulose is here formed by the protoplasm of the cells, in the same way as is that which constitutes the thickening layers of the cell-walls of the vegetative part of the plant.

The mechanism of the storage of sugar is not accurately known, but we may argue from analogy that it is brought about by the living substance of the cells, by which also, though diffusible, it is no doubt retained within them.

Proteids are stored similarly; in the meshes of the protoplasm of all cells there is a certain accumulation in amorphous

form. In many seeds they are deposited in the form of grains of complex nature, and sometimes of elaborate structure. Grains of proteid material are known as *aleurone* grains. Sometimes they are small, rounded and structureless, as in the Pea (*fig.* 1190). In other seeds, as in the castor-oil plant, they are much larger, of rounded or ovoid form, and contain a crystal of proteid matter, which often occupies nearly their whole substance (*fig.* 1191). This has been called a *crystalloid*. There is in such cases also a small aggregation of mineral matter which lies close to the crystal. This is known as a *globoid*, and consists of a double phosphate of calcium and magnesium.

The proteids of the aleurone grain are generally mixtures of

FIG. 1190.

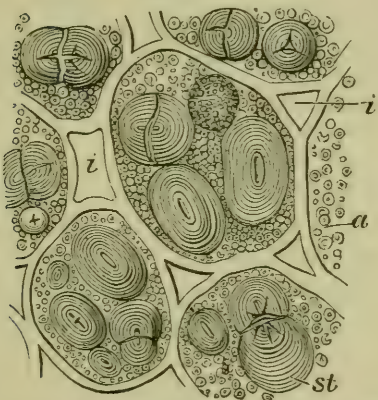


FIG. 1191.

Fig. 1190. Cells of a very thin section through a cotyledon of the embryo in a ripe seed of the common Pea (*Pisum sativum*). *a*, *a*. Aleurone grains. *st*. Starch granules. *i*, *i*. Intercellular spaces. (After Sachs.)——*Fig.* 1191. Cell from the endosperm or albumen of the seed of the Castor-oil plant (*Ricinus communis*) in dilute glycerine, showing large transparent proteid or aleurone grains, with crystalloids and globoids embedded in them. (After Sachs.)

globulins and albumoses, the latter being least in quantity. If a section of a castor-oil seed from which the oil has been removed, be irrigated with water, a part of the outer substance of the grain is dissolved, leaving still an ovoid body, in which the crystal, or crystalloid, can be seen. The part dissolved consists of the albumose, which is soluble in water. If the section be then irrigated with a ten per cent. solution of common salt, the body of the grain dissolves. This is composed of a particular globulin. The crystalloid will dissolve if it be treated with a saturated solution of the same salt, showing it to be made up of another globulin.

Other aleurone grains show other peculiarities of solubility,

but probably no other kind of proteid is usually present. Some, however, are thought to be composed of albuminates, as they dissolve only in potassic or sodic hydrate, or other alkalies.

The aleurone grains are frequently associated in the cells of the seed with either starch or oil. Occasionally both these compounds are present.

In other cases the reserves of proteid are crystalline in structure. Crystals of this character are easily found in the tuber of the potato, lying in the cells very near the epidermis. They are also met with in the thallus of certain seaweeds. Many of them can be made to crystallise from the solvents which are used to extract them.

The mode of formation of these aleurone grains is still not certainly known. Some authors regard them as deposited by a process something like crystallisation following the abstraction of water from the cell. Others have described their formation as one of secretion by the protoplasm. The latter view seems the more probable one.

Fats or oils occur copiously in certain seeds, such as those of the castor-oil plant (*Ricinus communis*), the Brazil-nut (*Bertholletia excelsa*) and others. They are found also in the cells of the floral leaves of many plants, and in many fruits. They are probably formed by the protoplasm, originating in small droplets in its meshes, which as the fat accumulates run together, till the cell is saturated with it. In some plants certain plastids have been described as forming oil, much as the leucoplasts do the starch grains. These bodies have been called *elaioplasts*.

Other reserve materials are known which are not so widespread as those already described. Such are the *glucosides* found in many of the Rosaceæ, the Cruciferæ, and allied orders. These are bodies which when decomposed give rise to a sugar, and various other bodies usually belonging to the so-called aromatic compounds. Amygdalin, found in the Cherry Laurel (*Prunus Laurocerasus*), may be mentioned as an example. When split up by chemical means, it gives rise to sugar, benzoic aldehyde, and hydrocyanic acid.

All these bodies, when acted upon by a process analogous to the digestion known in the animal kingdom, are converted into materials which can directly nourish the living substance, or can be transported easily about the plant in a condition of which the latter can readily take advantage, needing indeed very little constructive change to fit it for actual assimilation.

CHAPTER IX.

DIGESTION OF RESERVE MATERIALS.

We have noticed in following the deposition of reserve materials that their permanent form differs from that which they assume for purposes of transport. They are generally insoluble, and almost always indiffusible, whereas they travel in the form of soluble, diffusible bodies. The removal of them from the seats of storage takes place at times dependent on the resumption of activity of growth or development; and as this removal is dependent upon the same methods of transport, they must undergo a process which, from analogy with similar processes in the animal body, may be described as *digestion*. They must, after such treatment, be presented to the protoplasm of the growing cells in much the same form or condition as that in which they were first constructed from the simple bodies absorbed.

There is no special region in the plant where digestion takes place. It may be looked for in any cell in which any form of reserve material is deposited.

We have seen again that in a few rare cases nitrogenous material is absorbed into the plant body through certain leaves or modified foliar organs. The insectivorous plants are materially assisted in their growth by capturing and digesting various insects. *Drosera* does this by means of its sticky leaves, which are furnished with peculiar outgrowths, which bend over and imprison any small insect which alights upon them. The leaf is covered with a sticky or glutinous secretion, which is poured out from these so-called tentacles, and the insect becomes entangled therein. The tentacles then close over the insect and emit a fluid which has the property of digesting the dead bodies so imprisoned, rendering the nitrogenous matters capable of absorption by the leaf tissue. *Dionæa* imprisons any insect visitors by a different mechanism, and digests them by a similar secretion. Many other plants have a similar power. Some plants, such as *Nepenthes* and *Sarracenia*, are furnished with large pitchers, which are modified leaves. These contain a watery fluid, and insects falling into the liquid are drowned. Their bodies become decomposed by the aid either of a secretion from glands in the leaf, or by the action of bacteria, and the pitcher absorbs into its tissues the nitrogenous products of the decomposition.

We have, then, to inquire how these processes of digestion, whether internal or external, are brought about.

The protoplasm, among its many properties, no doubt has the power of setting up these decompositions, and probably in many of the lowest forms the work is altogether effected by its instrumentality. Indeed, in every cell of a complex plant the living substance is in a constant state of change, initiating many decompositions in which its own substance takes part, and many others into which it does not enter itself.

Though all protoplasm has this power, it is not usual in plants, any more than in animals, to find it exclusively relying on it. Usually the work is done by peculiar bodies which it forms or *secretes* for the purpose. We have in plants a large number of these secretions, which are known as *enzymes* or *unorganised ferments*.

The action of these bodies is not at all completely understood. They appear to take no part in the composition of the bodies which are formed by their activity, and they seem capable of carrying out an almost indefinite amount of such work, without being used up in the process. They are inactive at a very low temperature, but effect their decompositions freely at the ordinary temperature of the plant. As the temperature rises their activity increases up to a certain point, which varies slightly for each enzyme, and is called its *optimum* point. It usually ranges between 30° and 45°C. If the temperature be raised above that point, the enzymes become less and less active as it rises, and at about 70°C. they are destroyed. They work best in darkness or very subdued light; if exposed to bright sunshine they are gradually decomposed. They are often injuriously affected by neutral salts, alkalies, or acids.

The enzymes are manufactured by the protoplasm of the various cells in which they occur, being produced from its own substance, in a manner somewhat similar to that of the formation of the cell-wall. Usually their presence is manifested by a marked granularity of the protoplasm, due to the formation in it of an antecedent substance, known as a *zymogen*, which is readily converted into the enzyme.

We find various degrees of completeness of differentiation of the cells which produce these enzymes. In the simplest cases, such as the mesophyll of the leaves of most plants, or the seeds of the Leguminosæ and other Natural Orders, or the tubers of the potato, the enzyme is found in all the cells which contain the reserve materials, so that an active transformation of the

latter is readily possible. In the horse-radish and many allied plants, the cells which form the enzyme do not themselves contain any reserve materials, but are situated among those which do, giving us as it were the starting-point of glands proper, whose special function it is to secrete these ferments. In some of the plants belonging to the Natural Orders *Capparidaceæ* and *Tropæolaceæ* the glandular cell divides several times to form a little mass or nodule of secreting cells, which must be regarded as a rudimentary gland, though it is not provided with any definite outlet or *duct*.

In the seed of many grasses where there is a special organ, the *scutellum*, to effect the absorption of the nutritive material of the endosperm and supply it to the growing embryo, the outer layer of cells of this organ, called its *epithelium*, is a very marked secreting structure, producing at least two enzymes, which it discharges into the endosperm to effect the decompositions that must precede absorption. The tentacles of Drosera, to which allusion has already been made, secrete an enzyme, which, along with a weak acid, is present in the glairy matter that they pour out over the captured insect. These tentacles and the secreting structures of the leaves of Dionæa and other plants, and possibly similar bodies in the pitcher of Nepenthes, must be regarded as actual glands, comparable to those of the animal body, though less complex in structure. Glandular hairs, which consist of a few cells situated on a stalk, are found in great numbers on other plants, especially some species of *Saxifraga*.

There are many of these enzymes present in different plants, the function of some of which is still not understood. Many, however, have been investigated with some completeness. They are usually classified, according to the materials on which they work, into four groups, viz. those which decompose respectively carbohydrates, proteids, glucosides, and fats or oils. In nearly every case the action is one of hydration, the body acted upon being generally made to take up water, and to undergo a subsequent decomposition.

Of those which act upon carbohydrates we have two varieties of *diastase*, which convert starch into maltose; *inulase* which forms another sugar, levulose, from inulin; *invertase*, which converts cane sugar into dextrose and levulose; *glucase*, which produces grape sugar from maltose; *cytase*, which hydrolyses cellulose, and *pectase*, which forms vegetable jelly from pectic substance occurring in the cell-wall. Of the second group *pepsin*

and *trypsin* convert albumins and globulins into peptones, the latter decomposing peptone into amide bodies. *Rennet* is probably a member of this group, but its function in vegetable metabolism is unknown. It possesses the power of clotting milk. The enzymes acting upon glucosides are many; the best known are *emulsin*, *myrosin*, *erythrozym*, and *rhamnase*. The fourth class has only one member which has been investigated at present, the glyceride enzyme that decomposes castor oil.

Diastase appears to exist in two varieties, distinguished from each other by their mode of action on the starch grain. One, called diastase of *translocation*, dissolves the grain slowly from without inwards; the other, diastase of *secretion*, disintegrates it by a process of corrosion before dissolving it. The first of these varieties has a very wide distribution in plants, being present almost everywhere. The second is the body formed by the glandular epithelium of the scutellum of the grasses.

The great function of diastase in the plant is to transform starch (and probably glycogen where it occurs) into maltose, or malt sugar. Wherever starch is formed, whether in the living leaf or in the reservoir set apart for storage, it must be regarded as a reserve material. It has a rather large molecule, but its exact formula is not thoroughly known. The formula $n\ (C_6H_{10}O_5)$ is taken to represent it, and the value of n is probably 5. The starch molecule is possibly composed of four amylin or dextrin-like groups, arranged about a fifth. It has been suggested that the first action of the diastase is the liberation of them from each other; and that four of them, by successive incorporation of water, are converted through a series of malto-dextrins into maltose, while the fifth withstands the action of the enzyme for a considerable time. After the enzyme has been acting for a short time the resulting product is found to be four parts maltose and one part dextrin. How far this series of decompositions represents what takes place in the plant is uncertain, but it is clear that the starch, which is insoluble, is converted into sugar, which can be removed to the part of the plant where it is required for building up the protoplasm.

Inulase occurs only in the tubers and roots of some of the Compositæ, where inulin is abundant. It appears to convert inulin into *levulose*, an intermediate body being formed in the process. Invertase is easily extracted from the Yeast plant; in which it is abundant. In flowering plants it has been found in the seeds, buds and leaves, and pollen grains. In other fungi than Saccharomyces it occurs in *Fusarum* and *Aspergillus*,

besides many bacteria. Its action is the hydrolysis of cane-sugar with the formation of dextrose and levulose, according to the equation

$$\underset{\text{Cane-sugar.}}{C_{12}H_{22}O_{11}} + H_2O = \underset{\text{Dextrose.}}{C_6H_{12}O_6} + \underset{\text{Levulose.}}{C_6H_{12}O_6}$$

Glucase occurs in the seed of the Maize. It converts maltose into dextrose.

Cytase is chiefly known in the germinating grain of the barley, where it is secreted by the scutellum together with the diastase. It dissolves the walls of the cells of the endosperm, setting them free and giving a curious mealy character to the grain. Its presence is suspected in the Palms, where large reserves of cellulose are found in the hard endosperm walls. The embryo dissolves these walls and absorbs their products, but whether the ferment has a free existence is not yet settled. Cytase abounds in certain Fungi belonging to the genus *Botrytis.*

Pectase is but little known, and its function is not very clear. It is recognised by its power of forming vegetable jelly from the pectic bodies of the cell-wall. This jelly appears to be a compound of pectic acid with calcium.

The proteolytic enzymes pepsin and trypsin appear both to be represented in plants, though to what extent the former exists is somewhat uncertain. It is the enzyme which is found in the insectivorous plants *Drosera*, *Dionæa*, and others, and it converts the native proteids of the insect's body into peptones, which are absorbed by the leaf. It only acts in the presence of a weak acid and is only formed by the plant when the gland has been stimulated by the absorption of nitrogenous matter. Trypsin has a much wider distribution, being known to exist in the fruits of the Papau (*Carica Papaya*), the Fig, a variety of the Melon (*Cucumis utilissimus*), and the Pine-apple (*Ananassa sativa*), also in many seeds, such as those of the Hemp, Flax, Barley, and Lupin. In the latter structures it is of especial value in the processes of germination, feeding the young seedling with nutritive proteid or nitrogenous matter until the time when it is able to begin the constructive processes.

It acts upon insoluble proteids, forming from them albumoses, peptones, and amides, such as leucin, tyrosin, and asparagin. The medium in which it works varies according to the source of the enzyme ; that prepared from the Papau requires a slightly alkaline one, that from the Lupin works best in a weak acid.

These tryptic ferments, no doubt, bring about hydrolysis of the proteid, though it is difficult to prove it by analysis.

Whether rennet is proteolytic it is difficult to say. In the animal body it effects a decomposition of one of the proteids of milk, but the work it does in the plant has still to be ascertained. It has a very wide distribution, existing in the fruits, flowers, seeds, and shoots of various plants.

The enzymes which decompose glucosides are numerous, and are varied in their distribution. A typical one is the emulsin of the bitter almond and cherry laurel, which splits up the glucoside *Amygdalin* according to the equation

$$\underset{\text{Amygdalin.}}{C_{20}H_{27}NO_{11}} + \underset{\text{Water.}}{2H_2O} = \underset{\text{Benzoic aldehyde.}}{C_6H_5COH} + \underset{\text{Prussic acid.}}{HCN} + \underset{\text{Sugar.}}{2\ (C_6H_{12}O_6)}$$

This is, as in other cases, a process of hydrolysis. This enzyme acts also on other glucosides. Myrosin, another of the group, is peculiar in that it effects its decomposition without causing the incorporation of water in the process; thus:

$$\underset{\text{Sinigrin.}}{C_{10}H_{18}NKS_2O_{10}} = \underset{\substack{\text{Sulphocyanate}\\\text{of allyl.}}}{C_3H_5CNS} + \underset{\text{Sugar.}}{C_6H_{12}O_6} + \underset{\substack{\text{Potassium-}\\\text{hydrogen}\\\text{sulphate.}}}{KHSO_4}$$

Others, such as rhamnase, existing in the seeds of *Rhamnus infectorius*, erythrozym in the Madder, populin in the bark of the Aspen, act similarly to emulsin on various glucosides.

The digestion of the glucosides, we may notice, is always accompanied by the formation of sugar, which is one of the products of their decomposition. The fate of the other bodies into which they split is not well ascertained, though there is some evidence that cyanogen compounds, even such as hydrocyanic or prussic acid, are used for nutritive purposes by certain plants.

The digestion of fat or oil has not been very fully investigated, though certain facts are known concerning its fate in germinating seeds. The digestion is generally accompanied by the production of starch grains in cells near the seat of digestion, and it was formerly considered that the starch arose directly from the oil. It appears now that the oil is split up by an enzyme, with the formation of a free fatty acid and glycerine. The fatty acid undergoes further decomposition, being oxidised into simpler acid bodies which are crystalline instead of being viscid like the fatty acid first liberated. These pass into the general body of the seedling. The glycerine in its turn is converted into some form of sugar, from which the

plastids of the seedling construct the starch which has been referred to, its formation indicating, as in other cases, a temporary surplus of carbohydrate supplies.

There are other enzymes with a more restricted distribution, about whose value to the plant little or nothing is at present known. The cells of a particular yeast plant, known as *Torula Ureæ*, decompose urea with the formation of ammonium carbonate, and an enzyme having the same power can be extracted from them. Many enzymes can be prepared from bacteria, which set up various changes in proteids, partly peptonising and partly putrefactive.

The fermentative activity of the protoplasm was alluded to at the opening of this chapter. One of the most familiar of its manifestations is the production of alcohol from sugar, which is set up by yeast and which goes on not only in the yeast-cell but in the fluid around it. The same transformation takes place in some ripe fruits, the protoplasm of their parenchymatous cells conducting the fermentation. Similar changes lead to the formation of acetic acid from alcohol by the fungus *Mycoderma aceti*, and of other acids in the cells of the higher plants. The dependence of these fermentations upon the vital activity of the protoplasm is evident from the fact that no enzyme can be extracted from any of these cells which can set up the particular changes in question.

It is not difficult to prepare the enzymes from the tissues in which they work, but it would be extremely rash to say that they are in anything like a pure condition when obtained. Nor is it easy to say much about their purification, as they are not known except in close connection with the substances on which they act, or with the products of the decompositions they initiate. There is, therefore, no known test of their purity.

They can be extracted by treating the tissue, which should be very finely divided or ground in a mortar, with glycerine or with solution of common salt, or with water containing a trace of an antiseptic. After a period of ten or twelve hours the extract should be strained and subsequently filtered, when the enzyme may be precipitated by strong alcohol. It is very evident that this will not yield it pure, for the solvents employed will dissolve many constituents of the tissue besides the enzymes, particularly proteids and sugars. The former will be thrown down with the enzyme by the alcohol.

CHAPTER X.

THE CATABOLIC PROCESSES.

We have seen that the object of all the processes of construction and digestion that we have examined so far has been to present to the protoplasm materials which it can incorporate into its own substance. The bodies which we have traced to it consist, in far the greatest part, of some form of sugar and of organic nitrogenous bodies, either proteids or the complex products of their decomposition, such as the amides. The protoplasm of the cell is continually reconstructing itself at the expense of such nutritive substances, which indeed constitute its food in the strict sense of the term. But there is also going on, side by side with this process of reconstruction, a decomposition of the substance of the protoplasm, involving a splitting off from its complex molecule of various bodies of great variety but of less complexity than the living substance itself. These often, in the first instance, include such carbohydrate and nitrogenous residues as it made use of in building itself up. These can again be used in reconstruction of the protoplasm or can be further broken down into simpler bodies still. So long as the protoplasm is living, it is continually in a state of change or chemical activity, undergoing reconstruction and decomposition continually.

Besides this power of initiating chemical changes in which it takes itself a prominent part, it is also the seat of a large number of processes of both oxidation and reduction which are continually going on in its meshes at the expense of the various materials which are found there, either from being transported from other cells or from being formed in the processes of the self-decomposition of the protoplasm.

The formation of simpler from more complex bodies by either of these methods constitutes what has been called the *catabolism* of the plants. It may sometimes go on to the extent of producing such simple bodies as CO_2 and water, which are given off from the organism. In most cases, however, the catabolic changes are not so far-reaching, and there remains in the plant a great accumulation of organic substance such as woody or corky tissue. The relatively small extent of the catabolism as compared with the anabolism finds its expression in the enormous bulk which many trees and other plants attain.

Some of these processes of catabolism or, as it is sometimes called, *destructive metabolism*, are directly applied to the production of substances which are of great use to the plant. The formation in this way of materials which are of value to the organism is generally called *secretion*. In other cases bodies are produced which are of no value to the plant and which are as far as possible withdrawn from the spheres of vital activity. Comparatively few of them are ever thrown off from the plant, but they are generally deposited in such regions as leaves which are about to be shed, or the bark of trees, which is a collection mainly of dead matter, or sometimes in special cells, or in cell-walls, or elsewhere. These bodies really correspond to excreta, and the processes of their formation are called processes of *excretion*. Many others occur whose meaning is still obscure, and these constitute what are often called the *bye-products* of metabolism.

Of the processes of secretion the most prominent perhaps is that of the formation of cell-walls. We have seen that in the division of a cell in any of the higher plants the nucleus divides by a series of complicated movements, and forms two daughter nuclei, which are at first connected together by a structure called the *spindle*. Along the fibrils of this spindle minute particles or granules, originating in the protoplasm, pass to form a plate of extreme tenuity across the cell midway between the two new nuclei. This plate soon undergoes a transformation into the ordinary cellulose of the plant. The cell-wall is thus seen to be formed from the protoplasm, or to be *secreted* by it, the granules of which it is at first composed being the result of decomposition set up in the living substance.

When cell-walls are growing in thickness or in surface, a similar decomposition of the protoplasm can be observed. Fresh granules can be seen to be deposited by the latter upon the surface of the original cell-wall, which are soon transformed into the first thickening layer of cellulose. In all cases, therefore, the formation of cellulose can be traced to the self-decomposition of the protoplasm.

A very similar phenomenon is observable in the formation of starch grains. In most cases this is brought about by the activity of a plastid, either a chloroplast or a leucoplast. We have seen that these structures may be regarded as specially differentiated protoplasmic bodies, and their mode of behaviour has been described. Building themselves up at the expense of sugar and probably nitrogenous residues remaining in the

meshes of their substance, they break down to a certain extent, splitting off a quantity of starch which is poured out by the leucoplasts or deposited in their interior by the chloroplasts, leading to the appearances already described. The formation of starch is thus a secretion by the plastid, just as that of cellulose is a secretion by the protoplasm of the cell. In those cases where small grains of starch are formed without the intervention of a plastid, the work is done by the protoplasm of the cell.

The most recent researches render it highly probable that the formation of aleurone grains is precisely similar in the way in which it is brought about.

The formation of fat is due to similar behaviour on the part of the protoplasm. It can be observed most easily in the case of certain Fungi, when they are not well nourished. The protoplasm is found to get less in amount, the vacuolation becomes very considerable, and the cavities are found to contain large drops of oil. The elaioplasts to which reference has been made behave similarly, their substance diminishing at the same time that fat or oil makes its appearance. The decomposition of the protoplasm is here not accompanied by much reconstruction, so that it is soon very greatly diminished in amount, while the fat, the product of the catabolic processes, increases.

The formation of the enzymes described in the last chapter is another instance of the same kind. These are gradually elaborated by the protoplasm from its own substance, their development being attended by the formation of granules much as is that of cellulose.

One of the most important of these secretions is the green colouring matter, *Chlorophyll*, which we have already seen is present in the form of a solution in the meshes of the chloroplasts. The formation of chlorophyll is a more specialised process than any of those which we have just been considering, and is dependent upon a variety of conditions. It probably involves not only the self-decomposition of the protoplasm, but also other processes taking place in its meshes.

The conditions necessary for the formation of chlorophyll are, 1st, access of light, 2nd, a particular range of temperature, 3rd, the presence of a minute quantity of iron in the plant. If a plant be cultivated from seed in darkness, the resulting seedling will not be green, but will have a yellowish-white colour. When examined by a microscope the plastids

will be found in the cells, but they will be tinged with a pale yellow pigment known as *etiolin*. When the etiolin is exposed to light it will rapidly become green, being in fact replaced by or converted into chlorophyll. The etiolin is in the first instance secreted by the protoplasm of the plastid, and subsequent changes take place about which little is known, converting it into chlorophyll. If the temperature be kept very low, the etiolin remains unchanged, even though light be admitted. Hence the first leaves of plants which spring up in the winter are frequently yellow and not green. The function of the iron is not understood; plants cultivated in such a medium that this element is not supplied to them have an appearance much like that of an etiolated plant. Their colour is even paler, indeed they are almost colourless, though the plastids are present. A supply of iron at once changes them to the normal appearance. Plants so suffering from the absence of iron are said to be *chlorotic*.

The excretions of plants, using the term in the wide sense indicated above, and not implying that they are thrown off from the plant body, are similarly produced. Perhaps the most frequently occurring instance of these is the sugary solution known as the nectar, which is so common in flowers. Other instances are the resin produced in the resin glands of the Conifers and of other trees, and the etherial oils found in special receptacles in the leaves and other parts. Mineral matters, chiefly carbonate and oxalate of calcium, are also formed. The carbonate is in some cases excreted on to the surface through special glands, as in certain Saxifrages; in others it is deposited in the substance of the cell-walls or of protrusions from them, as in the cystoliths of Ficus, the Nettle, and other plants. The oxalate is frequently deposited in special cells, where it forms the bodies described as raphides and sphæraphides. In these cases the cluster of crystals is usually invested by a delicate skin derived from the protoplasm. The oxalate is also sometimes deposited in the substance of the cell-wall as in the bast fibres of *Ephedra*. Silica, again, is accumulated in the epidermis of many grasses and Equisetums.

Many of these excretions cannot be traced to the self-decomposition of the protoplasm, but are probably formed by the processes of oxidation and reduction which we have seen are often associated with its activity. They are not, however, formed withont its intervention in some way.

The bye-products of metabolism are too numerous to be

discussed in detail in the present treatise. They include bodies of varying degrees of complexity, some nitrogenous, others not. Among the former may be mentioned many compounds of the amides with fatty acids, xanthin and bodies allied to it, and the great group of the alkaloids. It is possible that many of these may be of use to the plant in its processes of reconstruction, but some are certainly of no value in this respect. The alkaloids come under the latter category, for though they contain combined nitrogen they cannot minister to the growth of the plant. If a plant is supplied with them, but with no other form of combined nitrogen, it is rapidly starved. The amidated fatty acids, leucin, tyrosin, glycin, &c., on the other hand, can be absorbed and utilised in the processes of nutrition. The latex of plants frequently contains many of these bodies. Caoutchouc is also present in some.

Among the non-nitrogenous bye-products may be mentioned the great variety of vegetable acids and many of the glucosides, such as salicin, coniferin, &c., which have a certain nutritive value owing largely to the sugar they contain. Certain other products derived from them may also be utilised in this way. Such bodies may perhaps be best included among the reserve materials already discussed. The vegetable acids, such as tartaric, malic, citric, &c., are usually regarded as arising in the course of the catabolic processes; it is, however, possible that some of them may be formed in the elaboration of food from the raw materials absorbed, having thus their origin in anabolism.

The bye-products include also a variety of aromatic substances, such as tannin, phloroglucin, and aromatic acids, such as benzoic, salicylic, &c., but the nature of the processes which give rise to them is not well understood.

Certain decomposition products of cellulose may also be included here. The lignin and suberin, which are characteristi of woody and corky cell-walls, arise in this way. During their formation they can be removed by appropriate solvents, leaving the cellulose skeleton which they are gradually replacing. These differ from most of the bodies described in that they can be produced in the walls of cells that have lost their protoplasm, so that their formation is independent of the latter.

Finally, we may include here the odorous substances and the colouring matters, except chlorophyll. Many colouring matters are the products of the decomposition of the latter, especially *xanthophyll* and *erythrophyll*, to which the autumn

tints of leaves are due. The former appears to be always present with chlorophyll in the chloroplasts.

Though many of these substances, both excretions and bye-products, are of no value for nutrition, some of them may play a very important part in the defence of plants against their natural enemies, their nauseous smell or flavour preventing their being eaten by animals, &c. Some odours and the nectar found in flowers are doubtless of great service in attracting insects, which assist in the process of cross-pollination, to be discussed in a subsequent chapter.

CHAPTER XI.

THE RESPIRATION OF PLANTS.

One of the conditions of life of almost every organism, whether animal or vegetable, is that it shall be supplied with free oxygen. Not only do all the vital activities of plants as well as animals depend upon this, but the very life of the protoplasm ceases if this gas is withdrawn. Consequently, as long as life is maintained, the organism must be continuously absorbing oxygen. This is very evident in the case of an animal, but it is not so obvious in that of a green plant, for the process of decomposing the CO_2 taken in as a material for food construction is, as we have seen, accompanied by an evolution of oxygen. In the case of a plant which has no chlorophyll the absorption of oxygen can be much more easily detected, as it is not masked by this converse process of its exhalation. If a fungus, such as a mushroom, be placed in a closed receiver containing ordinary air, and be left there for some hours, at the conclusion of the experiment the vessel will be found to contain but little oxygen, which will have been replaced by about an equal amount of CO_2. It is not difficult to devise an experiment which will show that a green plant has the same absorbing power. If the light be excluded from one placed in a similar vessel, no evolution of oxygen will take place from it, as we have already noticed in a preceding chapter, and that the oxygen diminishes even to extinction can be made evident just as in the case of the mushroom. We have, however, evidence that this is not caused by the exclusion of the light. An apparatus can be easily arranged to show the absorption of oxygen even when a green plant is exposed to a bright sunlight. The atmosphere in which the plant is placed can be freed from

CO_2 by having a vessel containing a solution of caustic potash in the receiver with the plant. The potash will absorb the CO_2 of the original atmosphere admitted, as well as any CO_2 given off by the plant during the experiment. If a capillary tube be fitted into the receiver and its other end be made to dip into a vessel of mercury, the latter will slowly and gradually rise in the tube, indicating a diminution of the volume of the included air. If the experiment be continued till the mercury ceases to rise in the tube and the gas remaining in the receiver be measured at the ordinary atmospheric pressure, it will be found that its volume has been diminished by about twenty per cent. and that what is left consists of nitrogen. The oxygen will have been completely removed by the green plant, even when in sunlight. If the caustic potash be examined, it will be found to have gained considerably in weight and to contain a quantity of carbonate of potassium. Thus there has been proceeding an absorption of oxygen, attended as before by an exhalation of CO_2, the latter having been combined with the potash.

This process of gaseous interchange constitutes what is known as *respiration*. Though more easily detected when the absorption of CO_2 and its decomposition by the chloroplasts are suspended, it is nevertheless constantly going on so long as the plant is living. It is observable in all living parts of the plant, whatever be their environment.

If the plant be carefully weighed at the beginning and end of the experiment, it will be found to have lost weight during its stay in the receiver, so that respiration is associated with a loss of weight to the plant. Not only is respiration attended with the emission of CO_2, but there is also a certain exhalation of watery vapour, which takes place quite independently of any supply from the root or the cut end of the stem. The nature of the metabolism is such that the living substance gives off both water and CO_2 while it coincidently absorbs oxygen. This is quite independent of any constructive processes, for it can be observed when no nutritive material of any kind is supplied to the plant.

We may inquire what is the relation of the absorption of oxygen to the elimination of CO_2 and water. It is conceivable that the oxygen may unite in the plant with carbon and with hydrogen to produce at once the exhaled compounds. A study of the living organism at work, however, soon shows us that the process is not of this simple nature. If a study be made of the germination of starchy seeds, the volume of oxygen absorbed

is about equal to that of CO_2 evolved, but if oily seeds be examined during germination, more oxygen is taken in in proportion to the CO_2 given out. Various observers have shown that in certain cases, succulent leaves, or the phylloclades of a Cactus, ar capable of absorbing oxygen without the simultaneous evolution of CO_2 at all. Nor is the oxygen absorbed without entering into chemical combination, for it cannot be extracted by the air-pump. Conversely CO_2 may be thrown off from a plant without any simultaneous absorption of oxygen. If a seed be germinated in a vacuum over a column of mercury, CO_2 is found to be evolved. Ripe fruits have been found to give off CO_2 in an atmosphere quite devoid of oxygen.

Again, it is found that the ratio of oxygen absorbed to CO_2 exhaled varies according to the temperature at which the experiment is conducted. Evidently the two processes are not directly dependent upon each other.

It is evident from the foregoing considerations that the vital activity of protoplasm is somehow associated with the two processes. In the absence of oxygen it gradually ceases, the living substance being in fact slowly asphyxiated. During its life one of the manifestations of its metabolism is the formation and exhalation of the two fairly simple compounds CO_2 and water. To ascertain what is the true relation of the two processes, it is necessary to look closely at the nature of the chemical changes going on in the protoplasm itself, or at what we have called its metabolism.

Respiration in the strict sense is, therefore, a process going on in the living substance itself, or rather is the expression of the beginning and end of a series of complex changes in which the molecules of the living substance are involved. The details of the absorption of the oxygen by the plant from its environment and the ultimate evolution of the CO_2 and water from the plant body should rather be regarded as the mechanism of respiration than respiration itself, which is a function of the living substance only. A distinction is often made by some writers between the two, the latter being spoken of as *intramolecular respiration.* It seems better on the whole to consider the latter phenomenon only under the name of respiration.

We see, then, that the two processes are not immediately connected in the sense of the CO_2 coming at once from the direct oxidation of carbon, but that they are ultimately associated, though separated in time by a series of chemical changes taking place in the living substance.

In the metabolic changes going on in the protoplasm we find, however, that while its own molecules are in a constant state of decomposition and reconstruction, other changes also take place in the various substances which are enclosed in its meshes, into which its own molecules do not enter. Processes of slow oxidation and gradual reduction are taking place there continually, excited, however, in all probability by the changes in the protoplasm itself. Even these, however, are by no means simple, and the direct oxidation of either carbon or hydrogen has probably no place amongst them. An instance of them may be seen in the oxidation of alcohol in the cells of *Mycoderma aceti*, a fungus which converts alcohol into acetic acid. This process, into which the molecule of protoplasm can apparently not enter, yet can only go on in the living cell. Other similar instances could be quoted.

The probable course of events is that the oxygen in some way unites with the molecule of protoplasm, rendering it unstable and initiating a series of decompositions which result in the formation of many of the bodies already spoken of in the last chapter. If the temperature be low, the breaking down of the protoplasm proceeds but slowly, and reconstruction, either from some of these residues or from food supplied to it from the cell contents, or both, is rapid. Consequently the quantity of oxygen absorbed or fixed by the protoplasm is greater than the quantity of CO_2 formed by its decomposition. At a higher temperature decomposition is much more easily carried on and its products are more numerous and simpler. The decomposition and recomposition go on side by side, simpler bodies being gradually produced, either by their splitting from the protoplasm directly, or by their being formed at the expense of the more complex decomposition products, during processes of slow oxidation in its meshes, till finally a certain production of CO_2 and water is arrived at. So long as the protoplasm remains alive the amount of these is not large, reconstruction continually taking place. When, however, the protoplasm dies, simpler bodies such as CO_2 water, and possibly *Ammonia* in addition, are produced abundantly from the decomposition which attends its death.

The CO_2 is thus the final term in a series of decompositions of which the living substance is the seat, and which are promoted by the access of oxygen. In some cases, such as that of the Cactus already alluded to, this final term is not reached, no CO_2 being exhaled. In these cases the process stops short at the

formation of certain organic acids which are found in abundance in the tissues of the plant.

In the case of certain micro-organisms there is no absorption of free oxygen; indeed these so-called *anaërobic* plants are killed by exposure to the gas. We must not, however, conclude that their metabolism is of a totally different kind from that of others, but rather that they obtain what oxygen they require from internal decompositions, or fermentative changes which they set up.

The meaning of these complex metabolic processes must be looked for in relation to the question of the energy which the plant requires for its vital functions. There are but two sources of energy available for its use; one of these, the radiant energy of the sun's rays, can only be utilised through the chloroplasts, and is not directly at the disposal of the protoplasm. But the construction by them of various complex materials, food and plant substance, involves the expenditure upon the latter of a considerable amount of this energy, which can be again set free by the decomposition of the complex bodies and the production of simpler ones from them. It is, of course, an every-day experience that the combustion of coal or wood, which is really the oxidation of its carbon and hydrogen to the condition of CO_2 and water, is attended with the liberation of a great deal of energy which takes the form of heat. So with the decompositions of the protoplasm which are set up, or at any rate facilitated, by the access of oxygen. The splitting up of the complex molecule, and the formation of simpler ones, at once set free certain potential energy, the amount being proportionate to the extent of the changes. Part of this energy is required at once by the protoplasm for the reconstruction or building up of its substance from some of the residues, but as some comparatively simple bodies, such as CO_2 and water, are always left to be given off, there is always liberated a certain amount of energy available for other work. In many cases this takes the form of heat. In germinating seeds and in the opening of flower-buds, where respiration is particularly active, there is always an appreciable rise of temperature, sufficient indeed to be measured by a thermometer. In other cases the released energy is utilised in causing movement; in a few instances occurring among certain fungi, it takes the form of light or phosphorescence.

The importance of respiration thus becomes evident; it marks the initiation, and is the accompaniment, of the catabolic pro-

cesses which we have discussed in the preceding chapter, and these coincidently place at the disposal of the plant a certain store of energy which, originally derived from the radiant energy of light, has been transformed from the kinetic to the potential condition, and which is rendered again kinetic by the catabolic changes. So constant is this relation that it may be said that heat is always evolved where and while oxygen is being absorbed.

Though respiration is always proceeding wherever there is living protoplasm, the activity of the process is modified by different physical conditions. The degree of illumination of most plants is continually varying, and though respiration does not depend upon light, its activity is not the same under all conditions of the latter. We have already noticed that variations of temperature affect differently the absorption of oxygen and the exhalation of CO_2. The absorption of oxygen is suspended if the temperature is too low, it increases as the latter rises to a certain optimum point, which varies with different plants, and at higher temperatures it progressively decreases. The exhalation of CO_2 is smaller at low temperatures than the absorption of oxygen, but is greater at higher ones.

The process of respiration is also affected to a considerable extent by the nature of the substances which serve as nutritive material for the reconstruction of the protoplasm. It has already been pointed out that seeds containing oil absorb more oxygen during germination than those whose reserve material is largely starch. Organs which contain much proteid matter respire more copiously than others which contain but little. The nature of the inorganic salts absorbed also influences the process to a certain extent.

CHAPTER XII.

GROWTH.

In studying the growth of plants we must consider the relation which it bears to the processes of metabolism which we have already discussed. We have seen that the constructive metabolism or anabolism is much greater than the destructive, or catabolism. There results from this a considerable increase in the substance of the plant, as well as an accumulation of potential energy which can be made available by the plant by the destruc-

tive processes. Usually we have therefore a great accumulation, which is primarily manifested in growth. Here again we must distinguish between the growth or increase of the living substance and the manufacture of other products such as wood, which is not necessarily living.

The growth of the living substance is always the result of constructive metabolism, and is attended by an increase of bulk and weight. The growth of an organ sometimes appears to be independent of such increase of weight; indeed, a diminution of the weight of the whole structure is sometimes noticeable. Thus, in the case of a potato allowed to germinate in such conditions as prevent the absorption of food materials from without, we have a marked change of form, but owing to the loss of moisture by transpiration and of CO_2 as a consequence of its respiration, or the catabolic processes going on in it, the resulting plant may weigh much less than the original potato.

This difference is, however, rather apparent than real. We shall see that the actual growth, or the manufacture of new cells, is confined to certain regions. In these regions there is a considerable increase in bulk and weight, but as the materials which are used for the purposes of this local growth are derived from substances stored up in the body of the tuber, the latter, which is not the seat of the growth at all, diminishes in weight and size to such an extent as more than to counterbalance the gain in the growing regions. Hence the whole plant weighs less than the tuber, though considerable growth may have taken place.

Growth is in the strict sense, then, always associated with the formation of new substance; it is in nearly all cases attended by a permanent change of form. This is perhaps not so evident in the case of axial organs, though here it takes place to a certain extent, as it is in that of leaves and their modifications. In most cases the young leaves of a plant have a different shape from the adult ones, and the appearance of the latter is gradually assumed as the leaf grows older.

This change of form not only can be seen in the case of such an organ as a leaf, but may be noticed also in that of the individual cells of which a plant consists. In the apical meristem of the shoot of a flowering plant the cells when first formed are almost cubical; after a little while we find many of them becoming prosenchymatous. Many other cases can be noted, particularly the irregularly shaped cells of the spongy

parenchyma of leaves, the stellate cells of the pith of certain rushes, the laticiferous cells of the Spurges, &c.

Growth may, in the light of the considerations advanced above, be defined as permanent increase of bulk attended by permanent change of form. We must not assume that increase of bulk is necessarily growth, for, as we shall see, in growing cells and members there is a constant stretching of the cell or tissue by hydrostatic pressure or turgidity which can be distinguished from growth by the fact that it can be removed, with the result of a certain amount of shrinkage of size of the part under examination.

Growth in the lowliest plants may be coextensive with the plant body. In all plants of any considerable size, however, it is localised in particular regions, and in them it is associated with the formation of new protoplasts. We have already seen in the case of the sporophytes of all the higher plants that there exist certain regions in which the cells are merismatic, that is, which have the power of cell-multiplication by means of division. In such regions, when a cell has reached a certain size, which varies with the individual, it divides into two, each of which increases to the original dimensions and then divides again. These regions have been called *growing points*; they may be apical, or intercalary, or may consist of definite layers known as *cambium* layers, or *phellogens*. By the activity of the protoplasts in these merismatic areas the substance of the plant is increased. As they consist of cells, it is evident that the growth of the entire organ or plant will depend on the behaviour of the cells of which it is composed.

The growth of a cell will be found to depend mainly upon four conditions: 1. There must be a supply of nutritive or plastic material at the expense of which the formation of protoplasm can take place. 2. There must be a supply of water to such an extent as to set up a certain hydrostatic pressure in the cell. This condition we have already considered in the first chapter of this section, where we discussed the relation of protoplasm to water. In the absence of this *turgescence* no growth is possible, for reasons that will presently appear. 3. There must be a certain temperature in the plant, for the activity of protoplasm can go on only within certain limits, which differ in the cases of different plants. 4. There must be a supply of oxygen to the growing cell, for, as we have seen, the protoplasm is dependent upon this gas for the performance of its vital functions. This is evident from the consideration that the

growth of the cells is attended by the growth in surface of the cell-wall, and as the latter is a secretion from the protoplasm, a product, that is, of its catabolic activity, such a decomposition cannot readily take place unless oxygen is admitted.

When these conditions are present the course of events appears to be the following; the young cell, immediately it is separated from its fellow, absorbs water, and with the water its contained nutrient substances. There is set up at once a certain hydrostatic pressure due to the turgidity, and the extensible cell-wall stretches, at first in all directions. The growth of the protoplasm at the expense of the nutritive matter for a time keeps pace with the increased size of the cell, but by and by it becomes vacuolated as more and more water is attracted into the interior. Eventually the protoplasm forms usually only a lining layer to the cell-wall, and a large vacuole filled with cell-sap occupies the centre. The growth of the protoplasm, though considerable, is therefore not commensurate with the increase in size of the cell. The stretching of the cell-wall by the hydrostatic pressure is fixed by secretion of new particles upon the original wall, which as it thus becomes slightly thicker is capable of still greater extensibility, much in the same way as a thick band of india-rubber is capable of greater stretching than a thin one. The increase in surface of the cell-wall is thus due firstly to the stretching caused by turgidity, and secondly to the formation of new cellulose upon the old. The latter only is the growth of the cell-walls; the former can be removed by irrigating the cell with a solution of a substance, such as common salt, which will rob the cell of its contained water. The constructive changes leading to the formation of new protoplasm are attended in this process by the catabolic formation of cell-wall and other substances, such as the osmotic bodies which are necessary to attract the water into the cell. The supply of oxygen is needed to allow the protoplasm to undergo these catabolic decompositions, enabling it thus to produce these several products and to gain from such decompositions the energy which must be expended upon the construction and reconstruction of the living substance and used in the secondary chemical changes which supervene.

This process of the growth of a cell is limited in its extent, though the limits vary very widely. In some cases cells grow only to a few times their original dimensions; in others they may attain a very considerable size. In any case, however, we can notice that the rate of growth is not constant; it begins

slowly, increases to a maximum, and then becomes gradually slower till it stops. The time occupied by these varying rates of growth is generally spoken of as the *grand period of growth*.

Changes in the shapes of cells arising during growth depend upon two factors. The direction of hydrostatic pressure and the power of the cell to respond to it may not continue the same in all directions, and, consequently, the growth of the cell in the direction of greater pressure or least resistance will be greater than elsewhere. The extensibility of the cell-wall may also be locally modified by the protoplasm, so that the growth becomes irregular, and cells of curious form may result.

If we consider the behaviour of a growing organ in the light of these facts, we shall see that it, like the cell, must show a grand period of growth. If we take the case of a root, in which the changes can be traced most easily from the simplicity of its structure, we find that just behind the apex the cells are all in active division. Growth is small, for the cells divide again as soon as they have reached a certain size. As new cells are continually formed in front of the merismatic mass, those behind gradually cease to divide, and the process of growth proper takes place. Here the actual extension in length of the root goes on, and the cells are at the maximum point of their grand period. They then gradually lose the power of growth, the oldest ones, or those furthest from the apex, parting with it first, and they pass over into the condition of the permanent tissue. Thus every portion of the root goes through a grand period of growth ; at first, when the cells are merismatic, growth is at a minimum, it gradually becomes accelerated, reaches a maximum, and slowly ceases, exactly as did that of the cell which we first considered. By careful examination of a growing root it can be found that the growth is greatest just behind the merismatic region. If a young root be taken and marked with a series of dots at equal distances apart, and then allowed to continue its growth, it will be found that the dots remain close together at the apex and for a very short distance from it. Then they become separated by broader spaces. Further back still the original intervals between the dots are again unaltered. The second region corresponds to the part where the cells are undergoing the enlargement described.

The same order of events may be ascertained to take place in the stem, but in this region it is complicated by the occurrence of nodes and internodes. Growth is confined to the latter, each of which passes through a similar grand period. The

growth of the stem is the algebraical sum of the growth of the internodes, many of which may be growing simultaneously. They will consequently be at different parts of their grand period at any particular moment. The region of growth in the stem is, as a rule, much longer than that of the root.

The growth of the leaf shows a little variation. The apical growth, as a rule, is not very long continued, and the subsequent enlargement of the leaf is due to an intercalary growing region near the base. This area has the merismatic cells at about its centre, and regions of greatest growth are on both sides of it. This can be traced more easily in the elongated leaves of Monocotyledons than in those of Dicotyledons.

The grand period itself is not quite uniform, as the rates of growth in the active region may and do vary with changes in external conditions, and with differences in activity in the protoplasm from time to time.

For the sake of simplicity of description it has been assumed in the foregoing account that the turgidity of the cells in the growing organ is uniform. This, however, is far from being the case. There is generally a fairly regular variation in this turgidity in the different parts of the growing organ. In the simplest case we may consider one which shows a difference in structure on two sides; such a member is described as *dorsiventral.* The two sides will often show a difference of degree of turgidity, and consequently of rate of growth. If we consider a leaf of the common Fern, we find that in its young condition it is closely rolled up, the upper or ventral surface being quite concealed. As it gets older, it gradually unfolds and expands into the adult form. This is due to the fact that in the young condition the turgidity and consequent growth are greater on the dorsal side of the leaf, so that it becomes convolute. As it gets older the maximum growth changes to the upper side, and so it becomes unfolded or expanded. These two conditions are generally described under the names of *hyponasty* and *epinasty* respectively.

These conditions are not confined to the leaves of ferns, but may be detected in those of other plants, though to a less degree. It is in consequence of them that the leaves of the bud always fold over the apex of the stem from which they spring.

Cylindrical organs may exhibit similar variations in growth. One side of a stem may be more turgid than another, and the maximum turgidity with its consequent growth may alternate between two opposite sides. The increased turgidity of the cells

is often accompanied by an increased extensibility of the cell-walls of the turgid region. The growing apex of such a stem will alternately incline first to one side and then to the other, exhibiting a kind of nodding movement in the two directions. This is known as *nutation*, and it is of very frequent occurrence.

The region of greatest turgidity, instead of being alternately on one side and the opposite, may pass gradually round the growing zone. The apex in this case will describe a circle, or rather a spiral, as it is elongating all the time, pointing to all points of the compass in succession. This movement has been described by Darwin as *circumnutation*, and has been said by him to be universal in all growing organs. The passage of the maximum turgidity round the stem may be regular or irregular, causing the circle to be replaced by an ellipse. Indeed, the simple nutation spoken of above may be regarded as only an extreme instance of the latter.

By these movements, incident to growth, and proceeding altogether from internal causes, many advantages are secured to the plant. In the case of climbing stems the circumnutation enables them to reach supports round which they twine, so that with but little expenditure of substance they can secure advantages of light and air which they could not obtain in its absence. The roots by the same method are enabled more easily to make their way through the crevices of the soil. The axis of the embryo shows in one or other of its parts strong hyponastic curvature, forming an arch, which enables it to leave the seed coats and make its way through the soil without damage to the young delicate plumule, its progress being helped by simultaneous circumnutation. On reaching the surface epinastic growth causes it to assume the erect position, while circumnutation of the apical region replaces that of the arched portion of the axis.

During the period of growth the young organ is extremely sensitive to changes in its environment, responding to such stimulating influences by further modifications of its behaviour; these will be considered in detail in the succeeding chapter.

Besides the hydrostatic tension set up in the cells of the growing regions, the processes of growth are accompanied by other tensions existing in their interior, which appear to depend upon differences between their tissue systems as these develop. If a petiole of Rhubarb be taken, and a thin strip be peeled from one side, it will immediately curl outwards. If it be then placed in apposition with the part from which it was cut, it

will be found to be appreciably shorter than the rest of the petiole. If the petiole be carefully measured, and then deprived of its cortical covering by separation of successive strips, the central part when measured will be found to be slightly longer than the original petiole. In such a petiole the central part was clearly compressed by the external portions, and when these were removed it underwent an extension which was the expression of the amount of such compression. Similarly the external parts were stretched longitudinally by the central region, and when they were freed from it, the recoil was accompanied by a diminution of their length. There was thus a longitudinal tension in the petiole, due to the turgescence of the central part, which stretched the outer portions, and was itself compressed by their greater rigidity resisting the hydrostatic extension. This tension is due not to greater growth, but to increased turgidity, for if the petiole be soaked for a while in salt solution till the water is in great part removed from its interior, and it has become flaccid, removal of the cortex is not accompanied by the same changes of dimension. A similar experiment may be performed on the hollow flower-stalk of a Dandelion. If it be slit into two halves by a vertical cut, the two parts curl outwards from each other, showing a similar tension in the internal regions.

Transverse tensions in growing stems can also be demonstrated. The cortex is found to be strained outwards by the pith, so that if a ring of it be cut out of the stem, it will be found to shorten on removal. The pith is in a state of compression, and the cortical tissues in one of extension, as in the other case quoted above. Transverse tensions of this kind are set up in the course of the thickening of stems and roots by the activity of the cambium layer, the bast and cortex being compressed outwards and the wood compressed inwards on account of the formation of the new material. This gives us a partial explanation of the formation of the annual rings of such stems and roots, and of the ruptures that are generally noticeable on the exterior of such parts.

In the absence of the external stimulating influences referred to above, growing organs show a tendency to grow in straight lines. Though the apex of any of them may continually show the movement of circumnutation, the mature part generally takes up a fixed position, growing vertically or horizontally as the case may be. This position is, however, usually the resultant of a number of external forces acting

upon the growing organ. The inherent tendency just spoken of can be satisfactorily seen only when, by artificially eliminating the action of such forces, the plant is not exposed to their stimulating influence. Such a tendency has been called *Rectipetality.*

CHAPTER XIII.

INFLUENCE OF THE ENVIRONMENT ON PLANTS.

According to the nature of their surroundings and the consequent differences in mode of life, we find in many plants certain peculiarities of form and structure which are different from those of the bulk of the forms which we have hitherto considered. Of these the Spermaphytes which live in water may be first discussed, as the direct influence of their environment is most conspicuous in their case.

These aquatic Phanerogams may be divided into two chief groups; those which are altogether submerged, and those which bear floating leaves as well as or instead of submerged ones.

In the former case the plant body may be attached by roots to the bottom of the stream or pool, or may be altogether floating. The stems are almost invariably long and slender, and easily swayed to and fro in the water. They depend for their support upon the nature of the medium in which they live, and though possessing a certain rigidity, this is not associated with any great development of woody tissue. Generally the latter is reduced to a minimum; the fibro-vascular bundles are usually few and contain few lignified elements. The substance of the plant is largely parenchymatous, and the cells have thin walls. The intercellular space system is often very complex, large lacunæ filled with air occupying a large space in the distribution of the tissues. Their rigidity is secured by the turgescence of the parenchymatous cells, and buoyancy is much assisted by the air in the lacunæ.

The primary root is generally feebly developed, and, as a rule, does not persist through the life of the plant. Adventitious roots, however, are given off in large numbers from the various nodes of the stem. The root-hairs which are so characteristic of terrestrial roots are usually either very scanty or altogether absent. The epidermis of both root and stem is not cuticularised,

but the cells remain capable of absorbing the water in which the plant is living. In the stem this tissue very frequently contains chloroplastids.

The character of the leaves differs in relation to the habitat. Those which grow in rapid streams are generally either long and thin, or are very much and finely divided, so that they offer in either case no resistance to the force of the current. In more sluggish water they are often broader, sometimes attaining a considerable size. Their tissue is always very weak, the parenchyma of the mesophyll sometimes being much reduced, so that as the leaf grows old it becomes latticed, as in *Ouvarandra*. The epidermis is never cuticularised, and it contains no stomata.

In plants with floating leaves the roots and stems are similar in character to those of the first class. The leaves, however, which lie upon the top of the water are usually tough and thick, their undersides being sometimes deeply rugose. They have not the much-divided outline characteristic of submerged leaves, but are usually simple and sometimes of considerable size. Those of the *Victoria regia* are often three feet in diameter, and are turned up at the edges, forming a rim, which helps to preserve the upper surface from being wetted. The upper epidermis of such floating leaves is often either strongly cuticularised or impregnated with a waxy secretion, serving the same purpose. The leaves are consequently shiny in appearance, and water will not adhere to them. These floating leaves bear their stomata upon the upper surface only.

The petioles are long and flexible and possess a peculiar power of adapting themselves to varying depths of water. Should the stream in which they live become shallow, the leaves still remain floating, owing to the power of the petiole to become curved; should the water rise, the petioles respond by renewing their growth, so as always to keep pace with the increased depth.

Vegetative reproduction is very common, branches becoming detached from the plant, which speedily put out adventitious roots of their own, and form new plants.

From their close relation to the watery environment and their power of absorbing liquid through their general epidermis, we can easily explain the absence of the woody tissue. Their transpiration is reduced to a minimum or altogether suppressed, and there is, therefore, no need of a provision for the rapid current of water so essential to the well-being of a terrestrial

plant. Their food materials reach them dissolved in the water in which they live, and hence they have no need of the complicated root system with its absorbent root-hairs, which is so characteristic of a plant growing in ordinary soil. Gaseous absorption takes place also through the general epidermis as well as from the cells of the lacunar passages.

It is noteworthy in this connection that the absence of the transpiration current is associated with a comparatively small development of the general plant body. Aquatic phanerogams are consequently never of large size.

The difference between the two groups spoken of may be well seen in such plants as *Cabomba*, which bears both submerged and floating leaves. These show respectively the characteristics described in each case.

Another class of plants which show a definite response in their structure to the conditions in which they live is that to which the so-called *xerophilous* plants belong. These are plants which grow in sandy deserts, exposed to great heat, and frequently undergoing long periods of drought. Those which are woody in habit show considerable tendency to diminish their leaf surface, probably to diminish evaporation and conserve their stock of water. Thus they often have many of their branches transformed into thorns or spines. Others which contain but little wood are succulent, and their surfaces are covered with a very thick and tough epidermis, which is strongly cuticularised. Many of them have leaves which show special absorbing structures that are often incrusted with chalk or a cake of salt. This becoming wetted by the dew gives up its captured water to the absorbing organ of the leaf, thus enabling the latter to make use of what in the absence of this mechanism would be lost to it. Many trees growing under the same conditions secrete a kind of resinous balsam, which coats the surface of their leaves and subserves a similar purpose. The water absorbed in this way is very rarely pure, but contains traces of sulphuric acid and ammonia, which, though trifling in amount, are no doubt of value in the nutritive processes. The adaptation to their environment which these plants exhibit is thus chiefly in the direction of economising a limited water supply.

The influence of the environment on the form of the plant body can be seen equally well in the case of such plants as grow in Alpine regions where the cold is usually intense, and the atmosphere for long periods so humid that transpiration is only possible at times, and where, consequently, the absorption of food

materials is much impeded. The plants are generally of comparatively small size and bear thick, often rolled-up, leaves, which are evergreen. The thick exterior and the general hardness of the leaf are a response to and a defence against the cold; the rolled-up leaves bear on their protected faces abundant stomata communicating with a relatively large spongy mesophyll, so that transpiration, when possible at all, may be rapid. The evergreen leaves also are an expression of the conflict against the difficulty of food absorption, which in such atmospheric conditions is possible for only a limited period of the year. By preserving its leaves green the plant can take advantage of every opportunity afforded it.

Some lowland plants show a similar response to their environment, the form and structure of different individuals of the same species varying to a certain extent, according to their advantages or the reverse, in such conditions as sunlight or shade, drought or moisture, exposure to or protection from cold winds, &c.

Epiphytic plants show some conspicuous modifications of their structure in consequence of their peculiar habit of life. They live usually upon the surfaces of trees, to which they cling by various means, but from which they derive no nourishment except such as is afforded by accumulations of débris, &c., upon the trunks. They are not parasitic, but merely live upon the tree as many other plants grow upon rocks or cliffs. Mosses and Liverworts are very largely epiphytic, as are certain species of Phanerogams; the latter are very specialised forms and show most adaptation of form and structure. Perhaps the most remarkable feature about them is their aerial adventitious roots which are given off in some cases from every node of the stem, so that each internode has its own supply. These are often long, cord-like structures which are of some thickness, often contain chloroplasts, and are either covered with a special epidermal development, or give rise to dense masses of root-hairs. In the first case, which is common among epiphytic orchids, the epidermis is many cells thick, and is known as the *velamen*. The cells are small tracheïds, with curious reticulated or spiral thickenings and often perforated. The cells are empty, or contain only air, and the velamen has consequently a curious glistening greenish appearance. The mass of tracheïds forms a kind of spongy covering to the root, and is capable of condensing and absorbing aqueous vapour from the moist atmosphere which usually surrounds it. The second case is illustrated by many aroids, and the dense plexus of root-hairs borne upon the aerial

roots serve the same purpose as the velamen of the orchids. Besides these roots, thus adapted to absorb watery vapour from the air, epiphytes have frequently others which are closely applied to the surface of the bark on which they are growing. These are often strap-shaped, and cling very closely to the tree, absorbing from the bark the soluble products of its decomposition and any mineral débris that may be accidentally carried thither. The small amount of such food stuffs available will explain the relatively large development of the root system, which is in much greater proportion than in ordinary land plants.

Parasites are another class of plants that have undergone much modification of structure in consequence of their mode of life. The parasitic habit is seen most completely in the group of Fungi, but it is by no means confined to them. We find many cases of partial or complete parasitism among flowering plants.

The fungus which is parasitic, derives all its nourishment from the plant or animal whose tissues it has invaded. Others of the same group are not parasitic, but live upon decomposing organic matter, being known as saprophytes. Their mode of nutrition is, however, essentially the same. In no case is chlorophyll present in the plant body, a fact which causes it to be unable to utilise and work up the food materials which green plants absorb from the air. Instead therefore of absorbing their carbon in the form of CO_2, these parasites must take it in the form of an organic compound of some complexity, which is usually some form of sugar. Their nitrogen can be absorbed much as that of a green plant, but they appear to utilise compounds of ammonia in preference to nitrates. No doubt their protoplasm is ultimately fed with the same materials as is that of the higher plants, but they lack a great deal of the constructive power of the latter.

Associated with the absence of the constructive processes which depend upon the presence of chlorophyll we have a great degradation of the plant structure. Their body is usually composed chiefly of delicate hyphæ, which ramify in the nutrient substratum, either living or dead, and which absorb elaborated products of some complexity freely by their whole surface. There is therefore no need of differentiated absorbing or conducting tissues, which are accordingly not developed. A further consequence of the ease with which they obtain their food is the readiness with which vegetative and asexual reproduction is brought about; hence sexuality in many cases is non-existent among them.

Phanerogams which are completely parasitic show a similar degradation of structure. They possess no chloroplasts, their leaves are absent or reduced to the condition of scales, while their stems are often thick and succulent. Their roots are the so-called *haustoria*, which penetrate into the tissues of their hosts and often complete fusion of the tissue of the host and the parasite takes place. Such parasites are represented in the British flora by the *Cuscutas* and the *Orobanchaceæ*.

Many of the plants belonging to the *Santalaceæ* and the *Scrophulariaceæ* show a partial parasitism of this kind. They have short stems bearing green functional leaves, but in addition their roots become attached by curious sucker-like bodies to the roots of other plants growing near them, and from these suckers absorbing cells are developed which penetrate into the substance of the hosts and draw nourishment from them. The Mistletoe behaves similarly, striking its haustoria into the tissue of the branches of the apple, oak, poplar, &c.; but here the parasitism is partly compensated by the fact that its leaves remain green when the host has lost its foliage, and by their activity they to some extent assist the tree on which the mistletoe is growing. The relationship seems to be almost one of *symbiosis* rather than of parasitism.

The habit of capturing insects, which we have seen to be characteristic of several plants of very different forms, may also be looked upon as connected with their environment. Many of them, as Drosera, grow upon a substratum largely composed of Sphagnum plants, which yield to them a very limited supply of nitrogenous matter; others are found growing on the surface of rocky mountains, into the chinks of the stones of which their roots penetrate; others again flourish in the sandy soil of deserts; in all of which situations compounds of nitrogen exist only in very small amount. The organic bodies yielded by the decomposing bodies of the captured insects may therefore form a valuable supplement to the ordinary sources of nitrogen.

Besides these influences of the environment, which are very far-reaching, and modify very largely the shape and structure of the plants exposed to them, ordinary terrestrial plants also show great power of reacting to the different external conditions which they meet. These will be considered in subsequent chapters.

CHAPTER XIV.

THE RELATION OF THE PLANT TO ITS ENVIRONMENT. IRRITABILITY.

We have seen in the last chapter that the peculiarities of form and structure which different plants present are to be associated with the character of their environment. From such facts as were there discussed it is evident that the plant is capable of receiving impressions from without, and responding to them in various ways. If we examine any plant which does not show such marked adaptation to its surroundings, we can find evidence of the possession of a similar power of appreciating differences in its external conditions, and of responding to them in various ways. Thus when certain zoospores of some of the lower Algæ, which swim freely in water, are suddenly exposed to a brilliant light, they at once take up a definite position with regard to it. When a leaf of *Mimosa pudica*, the so-called *sensitive plant*, is roughly handled, it falls from its normal position and takes up a new one, while its leaflets become folded together; when a filament of Mesocarpus is exposed to an electric shock sent through the water in which it is floating, it is found not infrequently that it splits up into its constituent cells. This power of receiving impressions from without is inherent in the protoplasm, and spoken of under the general term *irritability*.

Not only does it depend upon the protoplasm, but the latter must be in a healthy condition to manifest it. When a dicotyledonous plant which has been growing under ordinary atmospheric conditions, exposed to diffused daylight, is removed into darkness and kept there for some time, it becomes incapable of thus being impressed by its surroundings. Nor is its irritability alone affected by the absence of light, for many of its parts, particularly its leaves, cease to grow under such conditions. The condition which is thus induced by light, and upon which the manifestations of irritability depend, is known as *Phototonus*.

Plants, then, when in a phototonic condition, have the power to respond in various ways to alterations in their environment. If we consider the nature of the environment in the case of ordinary terrestrial plants, we find it usually as follows: the root system is embedded in the soil, among the particles of which the young root-branches ramify, and to them the root-hairs become firmly attached; the stem rises vertically into the

air and bears its branches and leaves ; the latter are consequently surrounded by air containing a varying amount of aqueous vapour. The aerial portion is subjected to the alternation of day and night, and during these it meets with considerable variations of temperature as well as moisture; the whole plant is constantly acted upon by the force of gravity. The subterranean parts also find considerable differences from time to time in the temperature of the soil, the amount of moisture which it contains, and the scanty amount of light which penetrates into the crevices between its particles. The environment, though to a certain extent constant, is nevertheless continually varying in these respects. Particular plants are also subject to other disturbances which are more special in their nature.

In considering the ways in which these various factors influence the behaviour of plants, we may study first their general relations to light of varying intensity, reaching them equally on all sides. We find many degrees of illumination, attaining in some cases an exceptional brilliance, as when a plant is exposed to the rays of a tropical sun. On the other hand we find cases where a plant is growing in almost total darkness.

If we consider first the latter case, we find such a plant much modified in form and structure. The stem is usually very much elongated and remains slender ; it is more succulent than the normal one, and bears extremely small leaves which grow out from it at a more acute angle than those which it bears when light has access to it. In cases where the stem is normally very small and the leaves are large and broad, the change in form is different. The stem is but little changed, but the leaves become much elongated and narrow. Certain phylloclades, such as those of some of the *Cacti*, become elongated and slender instead of being broad and leaf-like. The structure, too, is modified ; the woody and sclerenchymatous elements are much reduced, and the parenchyma of the cortex is increased in bulk. It becomes more succulent, and the reaction of its sap is much more acid. The chloroplasts do not become green, the pigment which they contain, known as *etiolin*, being a pale yellow. In the leaves the differentiation of the mesophyll into palisade and spongy parenchyma does not take place. The parenchymatous cells of the ground tissue of the stem usually become considerably elongated ; they have, indeed, grown much more than when the plant receives the normal amount of illumination. Plants thus affected by darkness are said to be *etiolated*.

That these changes are to be attributed to the absence of the light can be seen by comparing two similar plants, the first cultivated in darkness and the second under ordinary conditions of illumination, the other conditions being kept the same for both.

The explanation of the changes is somewhat difficult. The absence of light is clearly the cause of the different colour, for we have seen that, under such conditions, the pigment chlorophyll is not formed, but is replaced by the yellow etiolin. When an etiolated plant is exposed to light, the etiolin is shortly replaced by chlorophyll and the plant becomes green. Etiolin appears, indeed, to be the antecedent of chlorophyll. The question of the non-development of the woody elements and the generally increased succulence is more difficult to explain, and many hypotheses have been advanced to account for it. There is a change in the metabolism, evidently, as shown by the greater production of organic acids, to the osmotic properties of which the increased succulence is partly due. The reason for this change of metabolism is, however, not explained. Diminished transpiration may, perhaps, account for a good deal, for, as we have seen, in the absence of light there is but little output of watery vapour.

It is significant in this connection that the parts which show the excessive growth are in all cases those in which the water accumulates as transpiration becomes checked. The effect must, however, ultimately depend upon the protoplasm, which we have seen regulates all these functions, and which is profoundly susceptible to the influence of the altered conditions.

If we now examine the effects of too brilliant an illumination, we find other changes taking place. Many plants which normally have their leaves so arranged as to expose their upper surfaces to the incident rays are found under bright sunlight to place them so that their edges and not their surfaces receive the light. This phenomenon has been called *Paraheliotropism.* The effect is to preserve the chlorophyll from the destruction which follows upon too bright an illumination.

Another phenomenon, having for its purpose the protection of the chlorophyll, can be seen in many ordinary dorsiventral leaves. When brilliantly illuminated they are of a lighter green colour than when shaded, and this is found to be due to a different arrangement of the chloroplasts in the two cases. In the leaf exposed to diffused light these are collected on the upper and lower walls of the superficial cells, and they present their broader surfaces to the incident rays. When the light is cut

off altogether for a considerable time and other conditions are unfavourable, they collect on the lateral and lower walls. In the illuminated leaf they are found to have partially rotated so as to present their edges instead of their surfaces to the light, and to have collected upon the lateral walls. In the first case the chloroplasts lie parallel to the surface of the organ; in the last they are at right angles to the surface. These two conditions are known as *epistrophe* and *apostrophe* respectively. When the conditions of the incidence of the light are altered,

Fig. 1192.

Fig. 1192. *Desmodium gyrans.* A. Stem with leaves during the day. B. A similar stem with leaves in the nocturnal position, pointing downwards. (After Darwin.)

the chloroplasts change their positions accordingly. We see in these phenomena a power of the protoplasm to respond to an increase of illumination in such a way as to protect the plant from injurious consequences.

The effect of light upon structure also can be noted in the case of such leaves as are brightly illuminated; the palisade parenchyma being much more fully developed than in leaves which have grown in the shade. Indeed, the differentiation of the mesophyll into palisade and spongy parenchyma may be traced to the difference of illumination which the two faces

receive, for when both are equally well lighted the palisade parenchyma appears on both sides, while etiolated leaves, as we have seen, do not develop this tissue at all.

From a general consideration of the facts briefly summarised above we may come to the conclusion that light tends to retard growth in length. This is definitely borne out by actual measurements of growing organs which have been simultaneously cultivated under the two conditions of light and darkness. This action of light is sometimes spoken of as a 'paratonic' influence.

Fig. 1193.

Fig. 1193. *Nicotiana glauca.* A. Shoots with leaves expanded during the day. B. The same in the nocturnal position, pointing vertically upwards. (After Darwin.)

It has been further ascertained that the rays of the spectrum which exercise this influence are those of high refrangibility, the blue and violet. To these rays the protoplasm seems to be excessively sensitive. No mere physical explanation, such as a dependence on turgidity, or change in mode of nutrition, is sufficient to account for the facts observed; they can only be referred to the power of the protoplasm to respond to the influence of the environment.

Rhythmic differences in the intensity of the illumination to which a plant is exposed, in some cases, exercise a very powerful

influence on the behaviour of its leaves. This is best seen in those plants whose leaves assume different positions during the day and the night. The sensitiveness to the alternation of light and darkness is not confined to ordinary foliage leaves, but in many cases is shared by cotyledons also. The degree of sensitiveness varies greatly in different plants.

This form of irritability is manifested in a very great degree by many of the Leguminosæ. *Mimosa pudica* is perhaps the most noteworthy of them all. When this plant is removed from light to darkness its leaflets close; on being restored to light they open again, but little time intervening before the change of position is assumed in either case. Another very good instance is afforded by *Desmodium gyrans*, the so-called *telegraph plant*. During the day its leaves are extended almost at right angles to the stem (*fig.* 1192 A); as night draws on the terminal leaflets droop until they assume a position almost or quite parallel to the stem (*fig.* 1192 B). Many others assume still more curious positions, in some cases becoming twisted on their petioles or folded together in various ways. In some, as in *Nicotiana glauca* (*fig.* 1193), they rise instead of falling, and become somewhat closely approximated to each other.

These changes of position are generally spoken of as *nyctitropic* or sleep movements, though the latter term is misleading if it be interpreted to mean a sleep similar to that of animals. It is not difficult to prove that these curious movements are effected in response to the stimulus of the alternation of light and darkness, or to a rhythmic difference in the amount of light which they receive. When a plant which changes the position of its leaves as described is placed for a time in darkness, the periodic movement is soon very much interfered with, and it ultimately stops. The cessation is not, however, abrupt, but in most plants the movements will continue for at least a day. Plants, again, which are found in other countries to show this sensibility will when cultivated in England perform the movements at the normal hours and not at times corresponding to day and night in the countries from which they come. Nor is it the mere alternation of day and night; it is rather the difference between the illumination they receive during the two periods that serves as the stimulus, for some of them will not assume the nocturnal position unless they have been brilliantly illuminated during the day. The degree of sensitiveness in this case is not so great as in those where the diurnal and nocturnal positions are always regularly assumed.

The peculiar movements which the leaves perform in response to the stimulus are brought about by different mechanisms in different cases. In young leaves they are attendant upon growth, and are brought about by variations of turgescence upon the two sides of the leaf or its petiole, which are frequently followed by growth. We have seen that during growth the internal turgescence varies a good deal and leads to the curious movements of nutation or circumnutation. The actual nyctitropic movement is in these cases a modification of the extent of the circumnutation and takes place in response to the stimulus. Those leaves which show it can be seen by careful observation to be circumnutating during the day. When they assume their nocturnal position it is generally effected by their describing a much longer ellipse than during their ordinary movement. In some cases only a single ellipse is described during the twenty-four hours; in others two ellipses, the nyctitropic one being much the greater in amplitude. In yet other cases several ellipses may be described in the same time. Adult leaves which show this movement do so by virtue of a special pulvinus, or development of the hypopodium. This becomes turgid alternately on its two faces, causing the leaf to droop and to rise accordingly. These leaves generally show the movement for a much longer period than those in which it is brought about by variations of turgescence followed sometimes by growth. This naturally follows from the fact that the growth of leaves is not as a rule very prolonged.

That these movements are essentially dependent on the power of the protoplasm to receive impressions from without can be seen from a study of the conditions under which they are performed. When the soil is too dry, or when from any other cause the protoplasm in the cells is not supplied with water in sufficient quantity, they cease. When the temperature is too low they are interfered with. Violent disturbance of the protoplasm by shaking the plant will in some cases prevent their occurrence for one or two nights.

The purpose of the movement is probably to protect the delicate leaves from excessive radiation, which affects them very prejudicially. Their upper surfaces are especially liable to be injured in this way, and it is noteworthy that in all cases these surfaces are most sheltered when they take up their nocturnal positions. Often the upper surfaces of leaflets are then closely approximated together; in *Bauhinia* the leaf folds upon its midrib as an axis, so as to hide completely the ventral face.

The relation of the plant to temperature may next be con-

sidered. Plants are affected by variations in temperature in ways very similar to those depending on changes in light. In this case again we may discriminate between a *tonic* and a *stimulating* influence, though both these afford evidence of the ability of the plant to receive impressions from its environment, and to respond to them in various ways. It is not, however, always easy to ascertain the effects due to changes in temperature alone, as usually other conditions, such as light and moisture, vary at the same time as the temperature changes.

As we have seen, the environment of the plant is partly the soil and partly the atmosphere, and the temperature of both may or may not vary simultaneously. The tonic effects of differences in the aerial temperature have already been alluded to more than once in discussing the metabolic processes. There is for each of these a particular temperature at which it progresses to the greatest advantage. At lower and at higher points the protoplasm is less active, and in each case there is a point below which activity ceases, and one above which also it does not go on. The same thing is true of the processes of growth. We call these points respectively the *optimum*, the *minimum*, and the *maximum* temperatures for each function. They vary for different functions, and they vary also for the same function in different plants. We have said that this may be called a *tonic* influence; the manifestation of it is seen constantly, and it modifies not only the functions under consideration, but also the general power of the plant to appreciate all the special stimulations that it from time to time receives. We cannot say definitely how it affects the protoplasm, but the constant round of activity, chemical and physical, which constitutes its life, goes on for some reason best at the optimun temperature, and is altogether suspended at the minimum one. At the maximum temperature the death of the protoplasm generally ensues. The average points of minimum, optimum, and maximum temperature in the case of metabolism are about 10°, 30°, and 50° C., though a good deal of difference can be seen in different plants. The points observable for growth are slightly lower than those noticed for metabolism.

Variation in the temperature of the soil has a considerable influence on the absorption of water by the root-hairs, and indirectly on the process of transpiration. It has been found experimentally that warming the soil is attended by an increase in the activity of both these functions. As the absorption of water by the root-hairs is regulated by the protoplasm they

contain, it is evident that this variation in activity is the expression of a form of irritability which it possesses.

An instance of the *stimulating* as contrasted with the *tonic* influence of variation in temperature is seen in the opening and closing of many flowers. Generally these are found to open in the morning and to close at night, a behaviour which is very similar to that of leaves showing nyctitropic movements. While the leaves described above respond readily to variations in the degree of illumination, flowers seem to be largely uninfluenced by these, but to respond rather to the differences in the temperature accompanying them. The variations, to be effective, must lie, however, within the range already indicated as being necessary for the manifestation of irritability at all. The response made by the floral leaves seems, as in the case of the foliage ones, to take the form of varying turgescence of the two sides of the growing part, followed in many cases by actual growth.

CHAPTER XV.

SPECIAL SENSITIVENESS AND ITS RESULTS.

Besides the general reactions of protoplasm to variations in those features of the environment which affect more or less the whole plant, we find instances of special sensitiveness in various parts to influences which are not appreciated by the whole of the living substance. Of these the most prominent are lateral light, gravity, contact with foreign bodies, and moisture. One or two other cases of special sensitiveness affecting only particular organisms may also be discussed.

Lateral Light.—The effect of the lateral incidence of light may be studied very easily in the case of young seedlings. When these are so placed that rays from a light-source illuminate one side of their stem, very soon a curvature is apparent in the part which is actively growing. This is of such a nature as to place the axis of the plant in a position parallel to the incident rays. It manifests itself sometimes very rapidly, at other times more slowly. This response to a lateral stimulation is not confined to the stems of seedlings, but may be seen to a greater or less degree in many adult plants. It is a matter of common observation that geraniums grown in a window all bend their stems towards the illuminated side.

The same stimulus may also produce in other cases the opposite effect. When a young root is exposed to it, it curves so as to place itself in the same position with regard to the incident rays, but with its growing apex placed in the opposite direction. Stems are said accordingly to grow towards, and roots away from, the light-source. This behaviour is not, however, confined to roots, it is exhibited by the tendrils of *Bignonia capreolata*, by the peduncles of *Cyclamen persicum*, and by many other organs.

Leaves in many cases show a similar sensitiveness, but the position they assume is different again. They place themselves so as to present their upper surfaces at right angles to the incident rays.

These three movements in response to the stimulus of the lateral light are spoken of as *heliotropism*, *apheliotropism*, and *diaheliotropism* respectively. The advantages thus secured are in some cases very obvious; thus the heliotropism of the stem places its leaves in the most favourable position for the action of the chlorophyll in decomposing the CO_2 they absorb; the apheliotropism of the root assists it in penetrating into the crevices of the soil. The tendrils of Bignonia are aided by it in coming into contact with a support about which they may twine, while the apheliotropism of the peduncles of Cyclamen, which are bent downwards in a hooked fashion, enables them to grow towards the soil, into which they press the capsule, thus burying the seeds.

The response to the stimulus varies sometimes with the age of the organ. Thus the hypocotyl of the Ivy is heliotropic when young, but becomes apheliotropic when old.

The sensitiveness varies very greatly in different organs. Some of the seedlings of *Phalaris* examined by Darwin responded to such a feeble degree of illumination that it was hardly sufficient to cast the shadow of a pencil upon a piece of white paper held close behind it. The rapidity of the response also varies, some organs bending almost immediately, while others do so much more slowly. To this point we shall return later. The movement of apheliotropism is usually much slower than that of heliotropism.

The bending is not caused by a direct interference of the light with the actual growing part. It would seem at first as if the retarding effort of light upon growth might explain the bending of the organ towards the light-source, the non-illuminated side continuing to grow while the illuminated one is

checked. This explanation is directly contradicted by the phenomenon of apheliotropism as exhibited by a root. It is moreover proved to be an insufficient explanation by the fact that the part which is sensitive to the stimulus is not the part which actually bends. Darwin showed this by amputating a small region about ·1 inch in length from the tip of the seedling, or by lightly covering the same part with an opaque cap, when he found that the heliotropic curvature did not take place. Further, when the part normally curving under the influence of the stimulus is mechanically hindered from bending, the curvature takes place at a part a little lower down, which normally remains straight.

When the lateral light is fairly intense, the resulting movement takes place uninterruptedly; when it is only weak, the position is assumed by a series of zigzag movements, indicating that the new movement is an exaggeration of the ordinary circumnutation of the part. When the final position is reached the organ is found to circumnutate about the new direction of the axis.

A somewhat similar response to a lateral light is exhibited by many unicellular organisms. When these are exposed to oblique illumination they take up a definite position with regard to the incident rays, placing their long axis parallel to them if the light is weak, and at right angles to them if it is intense. This behaviour is known as *Phototaxis*; it is exhibited by the zoospores of many of the Algæ and by certain Desmids.

Gravity.—The force of gravity exerts an influence upon plants somewhat resembling that of lateral illumination. Thus most stems grow vertically upwards into the air; primary roots grow vertically downwards into the soil. A few organs, such as certain rhizomes, the stolons of many plants, and most secondary roots, grow at right angles to the direction of gravity. When one of these is placed at an angle from the position it usually takes, a curvature of the growing region results, which lasts till the normal attitude is regained. Thus when a young seedling is detached from the earth and laid upon its side, the stem gradually curves through an angle of 90° and becomes erect, while the young root curves in the opposite direction till it points vertically downwards. Similarly when a stolon is placed vertically, its apex is slowly deflected until it is parallel with the soil. These movements are termed *apogeotropism*, *geotropism*, and *diageotropism* respectively.

To prove these movements to be responses to the stimulus

of gravity, it is necessary to eliminate the action of the latter force and to observe the direction of growth under the new conditions. This can be done by causing the plant to grow upon an apparatus known as a *Klinostat*, which is a wheel rotating upon a horizontal axis at a regular rate, a complete revolution being made in about twenty minutes. The plant is placed in a horizontal position on the revolving wheel, so that each side of the axis comes alternately under the influence of the force. All parts of it are so affected equally, and it is found that then no curvature of the horizontal axis of the plant occurs in either direction. Another experiment, due to Knight, pointing to the same conclusion, is that of growing a plant upon a rapidly revolving wheel mounted on a vertical axis. When the wheel revolves sufficiently rapidly, though the plant is exposed all the time to the action of gravity, the centrifugal force of the apparatus is so much greater than the force of gravity that the plant does not respond to the latter. Instead, it responds to the stimulus of the rapid rotation, and the roots grow outwards from the centre of the wheel, while the stem grows inwards towards it. The force acts much like that of gravity, and the plant responds to it in a similar way, the root growing in the direction of the force and the stem in one opposite to it.

As in the case of heliotropism, the part which receives or is sensitive to the stimulus is not the part which curves. In the case of a root it has been demonstrated by Darwin, and more recently by Pfeffer, that the sensitive part is the tip, while the curvature is some distance further back, where active growth is taking place.

As in the former case, the movement of geotropism or apogeotropism is not confined to growing organs. When the haulm of a grass is placed horizontally on the ground, as is the case when a patch of wheat or other grass is beaten down by wind or storm, it after a time again becomes erect. The new position is due to the renewal of growth on the under side of the swollen nodes, which is excited by the stimulus and proceeds till the stem is again vertical.

As in the case of heliotropism, the sensitiveness varies very much in different plants. The movement is usually a modification of circumnutation.

CONTACT WITH A FOREIGN BODY.—Many instances of sensitiveness to this form of stimulus have been observed. When a leaf of *Mimosa pudica* is handled, the leaflets all droop downwards with great suddenness, and if the handling is very rough all

the leaves on the plant behave similarly. When a stamen of *Berberis* is touched at a point a little below the anther, the whole stamen bends forwards towards the pistil. The stigma of *Mimulus*, which is normally composed of two lobes extending outwards from each other, will, if either lobe is touched with a fine point, close, so that the upper surfaces come into contact with each other. When an insect alights on the surface of a leaf of Drosera, the tentacles with which it is furnished slowly curl over so that their terminal glands are brought together at the point of irritation; and at the same time the glands pour out a viscid, slightly acid secretion which is capable of digesting the proteids of the insect's body. The leaf of Dionæa, the Venus's fly-trap, which is normally widely expanded, closes with great rapidity when one of the six sensitive hairs which spring from its upper surface is touched. The leaf closes as if the midrib were a hinge, approximating the upper surfaces on each side so as to imprison the body which touches it.

This form of sensitiveness is peculiarly characteristic of the growing apex of young roots. If a seedling bean is taken, and a small piece of cardboard is attached to one side of the tip, a curvature speedily results which causes the root to bend away from the irritating body. If the movement takes the sensitive part away from the latter, the curvature is slight, but if, as in the experiment, the foreign body accompanies it in its displacement, the curvature will continue until the root is coiled completely round. The stimulus in the case of this movement must be prolonged, differing thus from the cases noted above, where a mere touch is sufficient to bring it about.

The cause of the curvature must be the sensitiveness of the protoplasm to the stimulus of contact. The movement cannot result from any injury done to the cells causing a hindrance to growth, for if this were the case the curvature would be towards the body touching the root, whereas it is in the opposite direction. If the cells of the side of the root at some distance from the tip are stimulated in this way, the curvature is round the stimulating body and not away from it. This may very likely be due to such a mechanical hindrance of the growth. In the first case, moreover, the part which shows the curvature is not the part irritated, but a region some little distance further back.

Perhaps the best instance of this susceptibility to slight contact is afforded by the behaviour of tendrils, the twining of these organs round their supports being altogether due to it. A very slight touch is sufficient to bring about a perceptible

curvature; in the case of the tendrils of *Passiflora gracilis*, indeed, Darwin found that the contact of a small loop of thread weighing not more than $\frac{1}{32}$ grain induced it, while a mere touch caused one to assume the form of a helix in about two minutes. This is perhaps the most sensitive tendril known; with others a stronger stimulus is needed and the time taken for the response is longer, the irritability varying greatly. The behaviour of tendrils in twining is somewhat peculiar. When young they are generally circumnutating, and if in their movement they come into contact with any foreign body they begin to curve towards it. If the contact be not prolonged, the tendril will curve for some time, but will ultimately become straight again and move as before, till it touches something else. If, on the other hand, the body first touched is one round which the tendril can twine, it coils itself round it; the stimulus thus persists and the resulting curvature increases it, till the support is encircled many times by the sensitive twiner. The coiling is seldom confined to the part of the tendril in contact with the support, but the free part between the latter and the axis of the plant also twists itself into a spiral coil. If the two be not very close together, this spiral usually shows two parts, the coils of which are in opposite directions. This is, however, only because the filamentous body is attached at both ends.

The tendril, though thus sensitive to contact, does not coil, according to Darwin, if its sensitive surface is struck by drops of rain, nor in the case of the Passiflora already alluded to, if contact takes place between two tendrils.

The sensitive region varies in different tendrils, but it cannot be so strictly localised as in the case of the growing root. They are usually irritable on one side only, which is slightly concave, though in some cases the sensitiveness extends all round them. The lower part of the tendril is, as a rule, only sensitive to prolonged contact. Their susceptibility further varies with their age, being greatest when they are about three parts grown. The part which first responds to the stimulus is usually the part touched, but, as we have seen, the coiling also takes place nearer their bases, so that we have an evident transmission of the stimulus backwards, as in other cases noted. The method of response is usually increased turgidity upon the convex side followed by greater growth, though in certain cases careful measurement has shown that the concave side becomes perceptibly shorter.

This sensitiveness to contact, which is so markedly shown

by tendrils, is possessed also, though to a much smaller extent, by most climbing stems, whose behaviour has already been described. It is shown also by the parasite *Cuscuta*, whose stem twines round those of other plants growing near its germinating seeds, and whose haustoria ultimately penetrate them. Twining petioles of similar behaviour are also met with.

Another form of irritability is exhibited by growing shoots, which is perhaps somewhat akin to sensitiveness to contact. If a shoot be struck laterally several times near its base, its apex curves over towards the side struck. If the blows be given near the apex, the curvature is in the opposite direction.

The mechanism whereby the response to the stimulus of contact is brought about in growing organs, we have seen to be an increased turgidity on the convex side, followed by growth. In those cases in which the organ is mature, it is evident that growth can have nothing to do with the movement. In these instances we have rather to do with a modification of turgescence, involving a redistribution of the water contained in the organ. The falling of the leaflets and leaves of *Mimosa* is due to a sudden change in the protoplasm of the cells in the lower side of its pulvinus, in consequence of which water escapes from them into the intercellular spaces between them. It is attended by a change of colour, the pulvinus becoming of a deeper green in consequence of the replacement of air there by water. If a leaf be cut off, and after the plant has recovered from the effects of the injury an adjacent leaf be sharply stimulated, water is seen to exude from the cut surface of the pulvinus. The cases of the irritable stamens and stigmas are probably to be explained similarly. The closing of the leaf of Dionæa is due also to a redistribution of the water in the cells, brought about by a rapid change in the protoplasm somewhat perhaps akin to contraction. In Drosera the inflexion of the tentacles has been found to be preceded by a peculiar churning movement of the protoplasm in the cells upon the side which becomes concave. This movement, which Darwin, who discovered it, called *aggregation*, is attended by a loss of turgidity.

Moisture.—Sensibility to variations in the moisture of the environment is not so widely distributed as are the forms of irritability hitherto discussed. It is exhibited chiefly by roots and by the rhizoids of the Hepaticeæ among green plants, and by the hyphæ of certain Fungi. These tend to curve in the direction of a moist surface if they are growing near one. When young seedlings are cultivated in a vessel which contains moist sawdust or

sand, and is perforated so as to allow the rootlets to protrude, these grow vertically downwards, according to their geotropism. As soon as they protrude, they curve to a greater or less extent towards the moist surface, as if seeking the moisture. This phenomenon is known as *hydrotropism.* The root-tip, as in other cases, is the sensitive part, while the curvature takes place further back, where growth is most active. Negative hydrotropism is very rare, being exhibited only by some of the Myxomycetes, which move away from moisture.

The advantage of this form of sensibility is evident in the case of the root, which, by virtue of it, is drawn towards the moisture of the soil as it penetrates between its particles.

A curious instance of appreciation of lack of moisture is afforded by *Porlieria hygrometrica*, which under such conditions closes its leaflets much as nyctitropic plants do when light gives place to darkness.

Chemical Stimuli.—Besides the forms of sensitiveness which we have discussed so far, there is evidence that vegetable protoplasm can appreciate stimuli of a different kind. These are less widely manifested, but instances are fairly abundant among the lower forms of plants.

A certain number of unicellular organisms are strongly affected by the presence of free oxygen. The most interesting case of this is that of *Bacterium termo*; when a number of these plants are placed in a drop of water on a slide, and examined under the microscope, they are found to aggregate at the edges of the cover-slip. If a small green Alga is placed in the drop with them and the slide exposed to light of a sufficient intensity to enable the decomposition of CO_2 to take place, the evolution of oxygen attracts the bacteria, which at once swarm round the alga. So sensitive are they to this attraction, that if the spectrum of sunlight is thrown upon the alga, the bacteria accumulate at those parts which are illuminated by the red and blue rays, the rays which we have seen to be capable of effecting the decomposition of the CO_2. This response to the attraction of oxygen is not confined to these bacteria; it is afforded by many zoospores, and also by the plasmodia of some of the Myxomycetes.

It has already been observed that when the necks of the archegonia of the Cryptogams open they discharge a certain mucilaginous fluid which attracts to the organ the free-swimming antherozoids. Careful experiments have been made in many cases to ascertain what is the nature of the attraction, and it has

been found that the mucilage contains various substances which the antherozoids seek. In the case of the Ferns, and some Selaginellas, it has been determined that the attractive body is malic acid. When a capillary tube containing a weak solution of this substance is inserted into water containing some of the antherozoids, they make their way very quickly to the orifice of the tube. In the case of Mosses the attractive substance is cane-sugar. That there is a definite attraction appears from the fact that strong solutions of either acids or alkalies are avoided by them with equal earnestness.

A similar behaviour marks the plasmodia of certain of the Myxomycetes. They move slowly towards a watery extract of tan, but retreat from a solution of sugar, glycerine, or certain neutral salts. Similarly, the zoospores of Saprolegnia are attracted by a solution of extract of meat.

The sensitive tentacles of Drosera can respond not only to contact, as before mentioned, but also to various substances placed upon the leaf. They are easily induced to bend by drops of liquid containing proteid matter, such as solution of albumen, or milk. Certain inorganic salts, notably carbonate of ammonia, produce the same effect.

A curious instance of this kind has been noted recently by Miyoshi. He cultivated certain fungi in gelatin containing a small proportion of sugar. Under the stratum in which the hyphæ were ramifying he placed another containing a larger proportion of sugar, and between the two arranged a membrane. The hyphæ very soon grew towards the stronger sugar solution, and to reach it penetrated the membrane.

Other instances of similar behaviour might be quoted. To this form of sensitiveness the name of *Chemiotaxis* has been given.

CHAPTER XVI.

THE NERVOUS MECHANISM OF PLANTS.

It is difficult to refrain from coming to the conclusion, from a consideration of the facts examined above, that the nervous system of the animal kingdom is represented in the vegetable one. That plants are sensitive to variations in the conditions surrounding them, and that the responses they make to such variations are purposeful, and conduce to the wellbeing of the

organism, is abundantly evident. The response to any external stimulus, moreover, has been seen to be dependent upon the plant being in a state of health and vigour. If its wellbeing has been interfered with by such disturbances as deprivation of light, or lack of oxygen, or exposure to too high or too low a temperature, no response is given, for its irritability is in abeyance or destroyed. Its own age again has been seen to have an important influence upon its power of receiving impressions and its behaviour in responding to them.

In considering from this point of view the way in which plants are affected by external influences, it is noteworthy that an exceedingly small stimulus is able to bring about a very considerable effect, and that there is no direct ratio between the intensity of the stimulus and the resulting movement. The tendrils of Passiflora, already alluded to, are caused to move by the contact with them of a small piece of thread, weighing not more than $\frac{1}{32}$ of a grain, and the resulting movement is of considerable extent and is prolonged for some time. The sensitive hair of the leaf of Dionæa needs only a touch to cause a rapid movement of the whole leaf-blade; the pricking of the staminal filament of Berberis causes a considerable movement of a relatively bulky body. The seedlings of Phalaris bend with some speed towards a light which is not sufficient to cause a visible shadow at the distance at which they are placed from it.

It can hardly be imagined that such slight disturbances can act mechanically upon the parts that move. This point is illustrated by the observation made by Wiesner, that if a part which responds only to the stimulus of lateral light be exposed for some time to such an illumination, and then, before the curvature has begun, be removed into darkness, it will slowly bend towards the side which has been stimulated. The same observation has been made by other observers in the case of the stimulus of gravity. There is no other explanation possible than that the stimulus brings about changes in the protoplasm of the cells of the moving part which slowly modify their relation to the water of their contents so that a great alteration of their turgidity results. Moreover the separation of the part stimulated and the cells which are the seat of the resulting action, implies that there must be in the plant a means of rapidly conducting such external impressions from one part to another. To this point we shall return.

If then we admit that there is even a rudimentary nervous

system in plants, we should expect to find a more or less evident differentiation of it in the direction of sense organs. This is in fact afforded in many cases. Darwin found that the seedlings of Phalaris were not sensitive to the faint light employed in his experiments except at a small region extending about $\frac{1}{10}$ inch from the apex. If this part were covered by an opaque screen in the shape of a small blackened cap, of not sufficient weight to cause any flexion of the stem, the seedlings no longer bent towards the light. Similar careful experiments made by the same observer pointed out that the tip of the young root was its only sensitive part. Other observers have proved the same thing. Cisielski amputated the tips of certain rootlets and laid them horizontally on a support. They then did not show any sensitiveness until they had recovered from the wound and a new root-tip was formed on each. As soon as the new tip was developed the rootlets showed a power of reacting to the force of gravity, and the curvature resulted in the usual place, More recently Pfeffer has demonstrated the same localisation. The whole leaf of Dionæa may be somewhat roughly handled without closing, so long as no contact is made with the hairs upon a particular portion of the blade. But so soon as one of these is touched the leaf closes. It is impossible to avoid the conclusion that we have to do here with a localisation of sensitiveness or the differentiation of sense organs. True the differentiation is anatomically very slight, but physiologically it is considerable. The same sense organ again is sensitive in very different degrees to different stimuli, and, as we should expect, to different strengths of the same stimulus. If a sensitive organ be acted upon at the same time by two stimuli which usually produce opposite movements, the resulting position is always that which would be caused by the stronger of the two.

One of the characteristic features of the nervous mechanism of an animal is the definite character of the response made to a stimulus. This point is also brought out in considering the behaviour of the parts under notice. If a root-tip is brought into contact with an obstacle, the bending is invariably in such a direction as to enable the root to pass it. When one is allowed to impinge upon a plate at right angles to its direction of growth, the curvature continues till the root has turned through a right angle and can grow parallel to the opposing surface. If on the other hand a part some little distance above the tip is obstructed, the curvature is towards the obstacle, a

course which serves the same purpose. The stimulus causing the movement of hydrotropism serves to bring the root-hairs into contact with the moist surface, thus enabling them to discharge their appropriate function. The behaviour of the tentacles of Drosera is very interesting in this connection. The leaf is of some size, and can therefore receive stimuli over a fairly large area. When the tentacles bend over in response to the alighting of an insect, they do not do so irregularly, but always place their glandular apices directly upon the spot which is the centre of the disturbance. This is very definitely purposeful, the invader being captured and digested wherever it alights, as all the tentacles are brought to bear upon it. The purposeful character of heliotropic and diaheliotropic curvatures is also very evident, the leaves being always placed thereby in the most favourable position for the discharge of their functions.

This special sensitiveness can be distinguished again from the general state of irritability in the plant. So long as the conditions remain favourable the latter is considerably prolonged, but the power of responding to particular impressions disappears much sooner. In some cases this power can be ascertained to have been lost by an organ while it still retains its power of circumnutating. The effect of a prolonged stimulation sometimes is to fail to produce a movement. Thus in the case of Dionæa, repeated touching of one of the hairs, if the leaf be prevented from closing, ultimately leads to such a touch having no effect when the leaf is released. This is a result of exhaustion or fatigue. At first it may seem doubtful whether or no the interference with the free response of the leaf may have so injured the motor mechanism as to make it incapable of acting. The exhaustion, however, is shown to be that of the hair and not of the hinge, by the fact that touching another of the hairs at once causes closure.

The nervous sensitiveness is by this and many other similar experiments shown to be capable of fatigue. A similar suspension of power may be demonstrated by exposing the sensitive parts to anæsthetics, such as the vapour of chloroform, ether, &c. The effect of these drugs at once suggests a similar action to that which they have on the nervous mechanism of an animal. When the effect of the fatigue or the anæsthetic has passed off, the organ again becomes capable of responding.

A nervous system generally can be shown to possess three distinct parts : one means whereby external stimulation is received and appreciated ; another whereby movements, &c., are caused ;

and a regulating and controlling part which can co-ordinate the response to stimulation, or can initiate movements, &c., in its absence. In the higher animals these are well differentiated from each other; we have the sense organs and the afferent nerves; the efferent nerves, connected with the motor and other mechanisms; and the nerve-cells which possess the co-ordinating power. In the much less differentiated plant-body the first two of these at least are recognisable. If we compare the sense organs of the animal with the sensitive parts of the plant, we find a certain correspondence, though it must not be pressed too far. The power of sight is very complete in the higher animals, in consequence of the highly differentiated character

Fig. 1194.

Fig. 1194. Continuity of the protoplasm of contiguous cells of the endosperm of a Palm seed (*Bentinckia*). *a*. Contracted protoplasm of a cell. *b*. A group of delicate protoplasmic fibrils passing through a pit in the cell-wall. (Highly magnified, after Gardiner.)

of the eye. In the lower animals it becomes less and less perfect, till in some it goes probably little further than the power of appreciating light. This power we have seen to be possessed by certain parts of the young seedlings of various plants in a very high degree, and by other organs to a less extent. The sense of touch may be compared with the power of responding to the stimulus of contact shown by tendrils and by the tips of roots; the muscular sense, or power of appreciating weight, is not dissimilar to the property of responding to the force of gravity, while the chemiotactic behaviour of the organisms described above suggests a rudimentary power of taste or smell, or both.

The conduction of the impulses received is due in animals

to the existence of differentiated nerves. The way in which it is carried out in plants has been much debated, but since the discovery of the continuity of the protoplasm through the cell-walls, there is little doubt that we have here a similar mechanism. There is scarcely any differentiation, but the power of the protoplasm to conduct disturbances from one part of the cell to another is a matter of common observation. The connecting strands between adjacent cells (*fig.* 1194) will suffice to suggest how impulses from the tip of the root may reach the growing cells.

The motor mechanism seems at first to be entirely different from that of the animal organism. Closer consideration, however, lessens the difference considerably. The contractile power is but little developed in vegetable protoplasm, but it has its representative in the power of resisting or assisting the transit of water. The effect is really similar in both cases; in the one the disturbance to the protoplasm leads to a contraction of its substance, in the other to its modifying its resistance to the passage of water through it. Each protoplasm responds in its own appropriate fashion.

The plant shows, however, an almost complete absence of the differentiation that reaches its highest point in the nerve-cell. There is apparently no co-ordinating mechanism which receives the impulses from the sense organs, and initiates in consequence the resulting movement. This need not, however, lead us to deny the existence of a nervous system, but only to remark upon the very slight degree to which it is differentiated. Darwin has called attention to one instance in which something of the kind is seen. When a tentacle of Drosera is stimulated, the actual bending is preceded by a curious motility of the protoplasm of the cells of its stalk which has been called *aggregation*. If a tentacle on the leaf is excited, the tentacles of the margin are gradually inflected towards the excited spot, as already described. If the cells of one of the marginal tentacles are watched during the experiment, their contents are found to undergo this aggregation, but those nearest its apex manifest it first. If the aggregation were the *direct* effect of the stimulus, those which it reached first, *i.e.* those nearest the base, would respond first. The stimulus, apparently, has to travel up the tentacle to the gland, and a disturbance to originate there in response, this disturbance travelling down the tentacle in the direction of its base. Darwin has pointed out that this corresponds in a measure to the reflex action of the animal organism.

If we are able from these considerations to recognise in the plant a nervous system in any way comparable to that of the higher animals, we are led to the view that the differences between the two are to be referred to differences of degree of differentiation. The latter is on the whole very slight in plants, nothing at all corresponding to the powers of consciousness or volition. There is, however, a differentiation in the sense organs in the direction of sensitiveness, which will equal if not surpass the powers of those of an animal. The tendril of Passiflora appreciates and responds to a pressure which cannot be detected by even the tongue; the seedlings of Phalaris readily obey the stimulus of an amount of light which is hardly perceptible by the human eye. The power of response to the stimulus is of course very much less than in the animal, but this, as we have seen, depends upon the differences in the motor mechanisms. In the vegetable protoplasm we have a much slower response, as well as one of a different kind, the effects taking as a rule longer to manifest themselves, and lasting for a longer time after the stimulus has been withdrawn. We have, however, as in the animal mechanism, a much better response to a cumulative or prolonged stimulation than to one which is rapid and transitory.

CHAPTER XVII.

AUTOMATISM.—RHYTHM.

The instances of sensibility we have been considering have been seen to be such as are manifested in response to external stimulation of various kinds. The responses made have been found usually to take the form of what are generally called movements of either the whole plant or of some of its members. Though called movements, however, they must not be interpreted in all cases to be such in the strict sense. They are rather changes of position brought about by varying turgescence, or alteration of the rate of growth in particular aggregations of cells. The protoplasm has been seen in many instances to play rather a passive than an active part in bringing about the change in position.

Besides these, however, we have yet to consider some similar phenomena in which the protoplasm is more directly concerned, and the nature of the stimulation, or the exciting cause of the

changes involved, is very obscure. Such phenomena are roughly classed together under the name of *automatism*, or *automatic movement.*

We have seen that certain plants at particular times emit from their body small masses of naked protoplasm which are furnished with a varying number of long filaments. These filaments, which are protoplasmic, are ordinarily in a state of active vibration, causing currents in the water in which they live, which float them quickly from place to place. Such free-swimming cells include the zoospores of the Algæ and the antherozoids of these and higher plants. The movement is brought about in the absence of any external stimulation, though the cells are capable of receiving such impulses. The cause of the movement is probably the contraction of each side of the filament, or *cilium*, alternately, or of the part of the cell just at its point of attachment. The impulse leading to the movement must be sought in some decomposition originating in the protoplasm itself, and not excited by any stimulus from without. The phenomenon is often spoken of as *ciliary motion.*

Of a somewhat similar character is the curious creeping movement of the Myxomycetous fungi. Each of the zoospores of these organisms consists of a mass of naked protoplasm which makes its way over the surface of its substratum by putting out blunt processes of its own substance, known as *pseudopodia.* These are protrusions of the ectoplasm, and the more fluid endoplasm is in some way drawn into them, so that the rest of the cell follows the movement of the pseudopodium. Which part of the operation really corresponds to the act of contraction is disputed, but it seems probable that it is the second, and that the first protrusion is of the nature rather of relaxation. In either case, however, the movement is independent of any external stimulation.

The *Diatoms*, which we have seen to form a sub-class of the Algæ, are capable of a curious gliding movement, which enables them to make their way with some rapidity through the water in which they live; they also are found to do this in the absence of any apparent stimulus; the *Oscillatoriæ*, which are filamentous algæ anchored to a substratum by one end of the filament, are also in constant wavy motion to and fro; a movement the mechanism of which is still unexplained, and which possibly resembles that of the diatoms. These are instances of the same automatism, the protoplasm in all probability originating the movement and carrying it out.

In certain lowly organisms such as *Chlamydomonas* there is to be seen in the protoplasm a clear space or vacuole, which exhibits a more or less regular pulsation, appearing slowly as a nearly spherical cavity, and then suddenly disappearing, recalling the active contraction of animal protoplasm. These, like the last-mentioned plants, are instances of movement in consequence of internal changes and not of external stimulation.

In the higher plants evidence of this special automatism is not lacking. Setting aside what is common to all plants, the inherent power of living substance to construct itself from food

Fig. 1195.

Fig. 1195. A portion of a branch, with a leaf, of *Desmodium gyrans*. The leaf, which is compound, consists of a large terminal leaflet, *a*, and two smaller lateral ones, *b*, *b*. There are also two other rudimentary leaflets, marked *c*, near the terminal leaflet.

materials, to carry on respiration and other vital functions, which are of course evidence of automatism, we have in a few cases distinct power of automatic movement. The protoplasm of the cells of the leaves of *Vallisneria*, of the internodal cells of *Chara*, of the pollen-tubes of many plants, of the cells of the staminal hairs of *Tradescantia*, and others quoted in discussing the structure of the cell, is in constant rotation round the cell, or movement within it in definite directions.

These instances impress upon us the belief that all protoplasm is the seat of active molecular movement, the intensity or vigour, however, varying very greatly in different cases. Indeed the

life of the protoplasm is intimately bound up with such a motile condition. Manifestations of this motility have from time to time been noticed above ; especially we may again allude to the regulation of turgescence, which we have seen to be one of the properties of vegetable living substance.

In many cases it can be noticed that these automatic movements set in with a certain definite intermittence, recurring, so long as conditions are constant, at regular intervals. The pulsating vacuoles already alluded to may be instanced in this connection. Such regularly intermittent actions may be described as *rhythmic* and the intermittence spoken of as rhythm.

When we look back upon the various functions we have examined we find evidence in them that rhythmic changes in the protoplasm are very widely met with in the life of the vegetable organism. Very conspicuous instances of it are afforded by certain movements often exhibited by the leaves of particular plants. Perhaps the most familiar of these is the so-called *telegraph* plant, *Desmodium gyrans*. The leaves are ternate, the terminal leaflet being very large in comparison with the two lateral ones (*fig.* 1195). If the plant be watched while exposed to a suitable temperature, the lateral leaflets are found to move up and down on the rachis, sometimes passing through an angle of 180°, and twisting slightly as they move. They thus describe a kind of ellipse, the duration of the movement being about two minutes. Many other instances of a similar kind are known, the Leguminosæ furnishing many examples. All of them do not exhibit them with the same ease, as they are much interfered with by the changes in position caused by external stimulation. They can often be made evident by keeping the plant either in the dark, or exposed to light of uniform intensity. Darkness, however, if too prolonged, results in the cessation of the movements, as these can only take place while the plants are in a condition of phototonus. The mechanism of the movement in most of these cases is the varying turgescence of pulvini at the bases of the leaflets. The alterations in this turgescence are the expression of rhythmic changes in the protoplasm of the cells.

The same rhythmic changes have place in all young growing organs, leading to the variations in turgidity that cause the movements of nutation and circumnutation which accompany growth.

The nyctitropic movements we have discussed may be quoted

in support of the existence of rhythm. Though they are ordinarily exhibited in response to the stimulus of alternate periods of light and darkness, many plants continue to exhibit them when altogether removed from light. That they cease after a day or two of darkness, is probably due to the fact that the plants are then no longer in a phototonic condition. Many flowers continue to open and close their corollas when removed from variable to constant conditions.

The same tendency to rhythmic change is shown in what is called the *periodicity* of the various vital functions. If, for instance, the root pressure of a plant be examined by the aid of the apparatus already described, in which the water taken up is made to support a column of mercury in a manometer, when the column of mercury has reached what we may call its *mean* or *average* height, it does not remain there, but begins to oscillate. It rises in the morning till about midday, then sinks somewhat, rises again towards the evening, and falls during the night. There is thus roughly a daily variation of the absorbent activity of the roots, which is very little affected by changes in the environment; it is in fact *automatic*.

There is a similar daily variation in the bulk of a plant, the diameter of the various organs diminishing from night till some time in the afternoon, and increasing thenceforward till dawn. These variations largely depend upon the distribution of the water which the plant contains, which is regulated by the living substance.

Many other instances of the same periodicity or rhythm might be quoted, but it is hardly necessary to multiply examples.

Though this rhythmic alteration of the protoplasm in various ways is no doubt inherent in plants, as appears from its occurrence when conditions are kept constant, it is easily affected by external causes. The effect of continuous darkness, we have already seen, is that the movements are made irregular and ultimately stop. In many cases the difference in degree of illumination between day and night affects the readiness with which the nyctitropic movements of the leaves are brought about. After brilliant sunshine they set in more quickly than after a dull light.

These movements may indeed show an artificially induced rhythm, superposed upon a normal one, in the same way as the movements of heliotropism, geotropism, &c., have been seen to be based upon the ordinary movement of circumnutation, to be, indeed, an exaggeration of it. In some cases the

tendency to rhythmic change can be manifested by the production of an altogether artificial rhythm, induced by submitting the plant to intermittent stimulation. Darwin and Pertz have described a very interesting experiment of this nature. A plant was fixed to a spindle placed horizontally, which, by an arrangement of clockwork, was made to make a semi-revolution at intervals of thirty minutes. The force of gravity thus exerted its effect on alternate sides for this interval of time, so that each side of the stem tended to become convex apogeotropically in turn. After a period of exposure upon the instrument the clockwork was stopped. Instead of the side which was then undermost increasing its convexity till the stem was vertical, the two sides continued to become alternately convex, as if the reversal of the instrument was still taking place. There was, in fact. an artificially induced rhythm manifested.

The conflict between the natural rhythm and the movement due to stimulation can be observed in the heliotropic curvature of many organs. The heliotropic position is not brought about by a direct movement of the organ, but by its describing a series of ellipses. The organ at the time of the incidence of the light stimulus is performing its ordinary circumnutation, the apex describing a circle. The effect of the stimulus is to turn that circle into an ellipse ; when the rhythmic impulse coincides with the stimulus of the light the movement is accelerated, and the resulting curve takes the direction of the long axis of the ellipse ; when the two act in the opposite direction to each other, the short curve of the same figure is described. The same result is obtained under the stimulus of geotropism.

The slow response to the action of a stimulating force may frequently be explained in the same way. Often, however, the long delay in responding is due to the sluggish nature of the protoplasm, a considerable time being taken up in inducing the necessary change in its motility. We have then what is called a *latent period*, before the manifestation of the irritability. Similarly the results of the stimulation continue for some time after the exciting cause is removed, giving what is called an *after effect*. An example of this is afforded by some experiments of Cisielski's ; he laid some geotropic roots horizontally on moist sand, and allowed them to remain there for some time. Before they began to show their geotropic curvature, he amputated the tips, which we have seen to be the sensitive parts or sense organs. After a time the geotropic curvature nevertheless took place. The stimulus was received while the roots

were intact, but its manifestation in the form of curvature took place as an after effect, even after the stimulus had altogether ceased to act.

CHAPTER XVIII.

REPRODUCTION.

The phenomena we have hitherto been considering all concern the life of the individual plant. As this, however, at the best is comparatively limited, we find plants endued with the power of giving rise to new individuals. The process of originating each new individual from its parent or parents is known as reproduction.

We have already seen that this process may be brought about in one of three ways. In the simplest cases, in what is known as *vegetative* reproduction, no special cell is produced for the purpose, but some part of the parent becomes detached and grows into the new individual at once. We see this easily in the reproduction of the lower Fungi, such as yeast, where the cell divides into two, which almost or quite immediately become free from each other, each being a yeast plant. It can be noticed through all the families of the vegetable kingdom, though as we advance upwards in the scale the new body becomes more and more complex. We have the gemmæ of certain Algæ and Bryophytes, which are multicellular; we have in many Mosses branches which become detached by the dying off of the shoot behind them; in many Ferns buds are developed upon the pinnæ of some of their leaves, which when separated from the latter grow into complete ferns. In the Phanerogams we find this method illustrated by cuttings, which are pieces of the stem bearing buds; these, when detached and planted in suitable soil, put out adventitious roots from the base of the cutting, and develop into plants like the original one. Another instance is afforded by the buds which many leaves, notably those of *Bryophyllum*, put out when wounded. These also develop adventitious roots, and young plants arise which become independent. Other plants produce underground buds, tubers, &c., as already noticed. One of the chief features of vegetative reproduction is that the new plant represents the same phase of the life cycle as its parent did. Thus the gemmæ of Mosses, which arise on the gametophyte, give rise to

other gametophytes; the buds of the ferns, the cuttings or buds of the Phanerogams develop into new sporophytes like their parents. Alternation of generations is thus left altogether unaffected by vegetative reproduction.

Some curious cases of this vegetative method are known. Thus in the embryo sac of *Cœlebogyne* there is no fertilisation of the oosphere, but still one or more embryos arise. This is caused by a vegetative budding of certain cells of the nucellus, which grow into the interior of the embryo sac and develop into embryos.

A further peculiarity of vegetative reproduction is that the new individual is developed continuously on its origination. There is no resting period, such as we find in most cases to mark the behaviour of the more specialised reproductive cells to be discussed below.

Besides vegetative reproduction we have two cases of the production of special cells to subserve this purpose. In the first of these cells are differentiated which, after a longer or shorter period of quiescence, can grow out into new plants. These cells, possessing in themselves the power of producing new individuals, are known as *asexual* cells. They are differently named according to the phase of the plant on which they originate; those borne upon the sporophyte being called *spores*, those on gametophytes *gonidia*. There is, however, no further difference between them; indeed, by many writers the name *spore* is applied to both.

The fact that they do not usually germinate till after a period of rest, though this is often not very prolonged, suggests that they originated in a need for the plant to develop certain cells which should possess the power of passing through times of unfavourable conditions without destruction. Such unfavourable conditions would be likely to kill the more delicate vegetative reproductive bodies. This view is supported by the fact that many of the lower plants, particularly *Yeast*, do not produce gonidia when conditions are suitable for the life of the ordinary individual, but can be made to do so by cultivating them under adverse conditions of moisture, food supply, &c.

The gonidia which occur upon the gametophytes of the Algæ and Fungi are produced in various ways; they may occur singly or in large or small numbers in the interior of particular cells known as gonidangia; they may be produced by abstriction from a cellular outgrowth of the thallus; in this case again the number produced from a single cell may vary within wide

limits. The various names given to them, such as *ascogonidia*, *stylogonidia*, *teleutogonidia*, indicate various conditions of this kind, and not any difference in their own structure. As a rule, they are small spherical or flattened bodies, clothed with a cell-wall; in both Algæ and Fungi cases occur where they have no such coating and are able to swim about by means of cilia. These forms are called *zoospores*, or *zoogonidia*.

In the higher plants, in which they originate only on the sporophyte, though possessing fundamentally the same structure as in the lower ones, their walls show more differentiation, possessing two coats, and often having the outer one curiously sculptured or furnished with projecting ridges or spines. Some have a third coat derived from the disintegrated mother cells and tapetum.

In some Pteridophyta an important variation makes its appearance; the spores are no longer all alike, but two kinds are produced, the microspores and the macrospores. This phenomenon is known as *heterospory*, and it extends also throughout the next group, the Phanerogams.

The microspores have the structure already described; the macrospores in the Pteridophyta are much like the microspores, except in size; in the Phanerogams they are simpler, having, with the exception of those of the Cycads, a single wall which remains thin and delicate. In this group too the macrospore is never set free from the sporangium, nor is the latter detached from the plant until after the germination of its spore.

The body produced from the germinating spore or gonidium is always a gametophyte, though often it only produces other gonidia.

In the second case in which there is a production of special reproductive cells, these are incapable alone of producing a new individual, but must fuse together in pairs to bring about this result. They are consequently called *sexual* cells or gametes. These probably took their origin from the asexual form. The phase of the plant on which they occur is always the gametophyte. The latter can consequently give rise to either sexual or asexual cells or both, while the sporophyte can only produce the latter.

In all the higher plants the gametophyte and sporophyte regularly alternate with each other, each producing the other phase of the life cycle. This phenomenon is known as *antithetical* alternation of generations. In the lower forms it is not at all regular in its occurrence; the sporophyte being altogether unrepresented in some, and only occurring at intervals in others.

We get in some of the former a succession of gametophytes, which reproduce themselves many times in succession by gonidia and do not develop sexual cells at all. After a number of generations have been thus produced asexually, a form arises which bears gametes, and these after fusion produce again a gametophyte which only develops gonidia. The gametophyte which does not develop its gametes is called a *potential* one, in contradistinction to one which does, and which is known as an *actual* gametophyte. The alternation of actual and potential gametophytes, where the resulting plant is in all cases similar to its parent, is called *homologous* alternation in contradistinction to antithetical, explained above. In such an alternation there is usually an absence of regularity, many potential gametophytes being developed in succession before an actual one arises.

The latter fact appears to indicate that in most plants continuous reproduction by asexual cells is attended with some deterioration of the plant's constitution, which becomes again invigorated by the occurrence of the sexual mode.

The phenomenon of heterospory involves the production of two gametophytes to one sporophyte, as each of the former produces its appropriate prothallus. Such plants show in their life cycle, therefore, three forms, one sporophyte, and two gametophytes, the latter occurring synchronously.

It is noticeable, further, that as we pass through the several divisions of the vegetable kingdom the predominant form of the plant changes. In the Thallophyta it is always the gametophyte ; the sporophyte is not universal there, and is never more than a small structure, which nearly always remains attached to the gametophyte. In the Bryophyta the two phases are more nearly alike in degree of development ; the gametophyte is always the vegetative body, while the sporophyte often shows the greater histological differentiation. It is always parasitic upon the gametophyte, and never attains a higher degree of morphological value than a thallus. In the Pteridophyta the sporophyte is the predominant form, and takes on the vegetative functions. The gametophyte shows continuous retrogression, and in the highest members of the group is almost entirely enclosed in the spore. In the Phanerogams the reduction in size is still more marked ; in the Angiosperms the female gametophyte consists of only a few cells developed in the interior of the spore, while the male one is a tubular outgrowth from the pollen grain.

The gametophyte was doubtless the primitive form of the

plant. The gradual appearance of the sporophyte can be observed still in the group of the Algæ. In Œdogonium the fertilised cell does not grow out into a new filament, but produces in its interior four zoospores which escape from it, and after a period of rest germinate and produce new plants. The fertilised cell here represents the sporophyte, which is reduced to a single sporangium. In Coleochæte the zygote is invested with a covering derived from the adjacent cells, and after sinking to the bottom of the water it germinates, producing inside its coating a small mass of cells, each one of which liberates a zoospore. There is here a sporophyte of a slightly higher type than that of Œdogonium. Somewhat more complex sporophytes occur among the Rhodophyceæ. An indication of the sporophyte may perhaps be seen in Spirogyra, where the nucleus of the fertilised cell divides into four, though no definite cells are formed. On germination of the zygote, however, only one filament grows out.

It was suggested above that probably the sexual cells were originally derived from asexual ones. A study of such forms as Hæmatococcus and Ulothrix leads us to this view. In the former two forms of zoogonidia are produced, which differ from each other only in size. In Ulothrix the same thing is seen, but there is a difference in their behaviour. The larger ones are asexual, but the smaller generally conjugate or fuse in pairs. They represent, therefore, the sexual cells or gametes. This is the more likely, as the cells which fuse are generally, if not always, produced by different plants. The sexuality is not, however, well pronounced, for if one does not become fused with another, it can still germinate independently.

The gradual differentiation of the gametes into definite male and female individuals has already been traced in the section on the Thallophyta. When completely differentiated the male cell, which is known as an antherozoid, is a small free-swimming body, furnished with cilia. This form, which is the most perfect known, is not, however, of universal occurrence. In the Fungi the male gamete is almost always an undifferentiated mass of protoplasm which sometimes becomes free from the cell in which it is produced, but is then clothed with a cell-wall and has no power of locomotion. Sometimes it is not set free until it actually passes into the oogonium. In the Rhodophyceæ it is similarly unciliated, though at first it is a naked cell. The same want of differentiation is seen in all the Phanerogams, where the male gamete is represented by a portion of the protoplasm of the pollen tube.

The female gamete is more uniform, being generally a larger mass of protoplasm, with no cell-wall, and in all but the lowest forms incapable of motion. Below the Chlorophyceæ it is always set free and is fertilised in the water; in and above that group it remains in the cell in which it is produced, an oogonium or an archegonium as the case may be. In the Angiosperms it is not even developed in an archegonium. A curious peculiarity is noticeable in the Rhodophyceæ, where the female organ, known as a procarp, contains no differentiated female cell. In the Ascomycetous fungi the same absence of differentiation is seen, though possibly here there is no sexuality.

The peculiarity of sexual reproduction is that the gametes are incapable of giving rise to a new individual without fusion of a male and female together. In this process nucleus unites with nucleus and protoplasm with protoplasm. In the fusion of the nuclei in the Phanerogams, however, the chromosomes do not unite, so that the nucleus of the zygote or fertilised cell has twice the number of these that that of each gamete possessed. When the zygote germinates, the first nuclear division is so carried out that each daughter-nucleus receives half the chromosomes from each sexual nucleus.

The cells which fuse may be alike, or may be dissimilar; in the former case the process is spoken of as *conjugation*, in the latter case *fertilisation*. The resulting body is called the zygospore or the oospore respectively; the term ‘zygote’ is now generally used instead of either of these. Conjugation only occurs among the comparatively undifferentiated Thallophyta.

The mode of bringing the gametes together varies with the habit of life of the plants. Where the antherozoid is motile it makes its way to the oosphere by means of its cilia, which enable it to swim freely in water. In those forms with a terrestrial habit, such as the Bryophyta and Pteridophyta, in which the antherozoid is ciliated, fertilisation can only be brought about when the gametophytes are moistened, as is the case from time to time. The antherozoids are attracted to the archegonia by some constituent of the mucilaginous matter which is excreted from their necks when they open. In the Mosses this has been ascertained to be cane-sugar; in the Ferns it is malic acid or one of its salts. In the Rhodophyceæ and such Ascomycetes as possess sexual reproduction the passive male gamete, known as a spermatium, is floated to the female organ or its trichogyne by currents in the water.

In the Phanerogams, where the female gametophyte is always

attached to the parent sporophyte, such a means of fertilisation is of course impossible. For fertilisation to occur it is necessary that the two gametophytes shall be produced in close propinquity to each other. This is effected by the bringing together of the two spores concerned in developing them. The microspore or pollen grain is carried by various means to the neighbourhood of the macrospore; in the Gymnosperms it falls upon the macrosporangium itself; in the Angiosperms upon the stigma of the pistil in which the macrosporangia are hidden. As it germinates, its gametophyte, the pollen-tube, makes its way through the intervening tissues till it reaches the macrospore itself, close to the archegonium in the first case, and to the oosphere when there is no archegonium. Fusion of the gametes produced in each gametophyte then becomes possible, and by a deliquescence of the separating walls they come into contact with each other and their union takes place.

In these higher plants we have two processes necessary for sexual reproduction, the one the approximation of the spores, or *pollination*, the other the fusion of the gametes, or *fertilisation*. Frequently the latter term is loosely and erroneously applied to the former process, as when the *fertilisation of flowers* is spoken of. The process is one of pollination, and may be followed by fertilisation or not according to circumstances.

When the cells which fuse are derived from the same gametophyte, the term *self-fertilisation* is applied to the process; when they come from different ones it is called cross-fertilisation. Self-fertilisation in the strict sense is extremely rare; even in the Thallophytes the uniting cells usually originate on different plants. The term 'self-fertilisation' has been used very generally to indicate the pollination of a pistil by pollen from the same flower; it is however better to speak of this as *self-pollination*. Speaking strictly, self-fertilisation cannot take place in heterosporous plants, as each spore produces its appropriate gametophyte and the two sexual cells never arise upon the same one. Cross-fertilisation has been found always to result in stronger and healthier plants than self-fertilisation. Cross-pollination, or the bringing together of spores from different flowers, or from different plants, of the same species, also yields more and better seeds than self-pollination.

Very many mechanisms have been developed in different plants to secure this end. Pollen may be carried from flower to flower by wind or water, or by the agency of insects or other

animals. From this point of view plants have been classed as *anemophilous* or wind-pollinated, *hydrophilous* or water-pollinated, *entomophilous* or insect-pollinated, or *zoophilous* or those pollinated by other animals.

Of these methods of pollination the anemophilous and the entomophilous are the most wide-spread. In the former case certain structural features are associated with the mode of transference of the pollen. It is produced in such flowers in great abundance, is extremely light and dry, and in some cases furnished with bladders to aid its transport. The receptive organ is sometimes a bulky cone, the leaves of which are separated from each other and from the common axis by spaces into which the pollen may drop; sometimes it is a much divided or plumose stigma, often furnished with hairs, so that pollen falling on it may be readily retained. The method is a wasteful one and involves the production of a superabundance of pollen. On the other hand anemophilous flowers are always inconspicuous and of a comparatively humble type.

Flowers which are pollinated by insects are usually much larger and more showy, not infrequently possessing irregular corollas, and are often very highly coloured and provided with characteristic odours. Their perianths and sometimes their sporophylls are highly modified to adapt them to the habits of their insect visitors. As a further attraction to the latter they usually produce honey in some part of the flower, in such a situation as will lead to the removal of pollen by the insect in its search for the attractive liquid. The pollen itself also is often the object of the insect's visit. Many special mechanisms to secure the removal of the pollen from the microsporophyll and its deposition upon the stigma of another flower are to be met with; indeed, almost every Natural Order shows some modification in this direction. The consideration of them in detail, however, is beyond our present purpose.

Something akin to cross-pollination occurs in Azolla as already described; the massulæ or collections of microspores being floated to the macrospores, to the floats of which the glochidia attach them.

These mechanical adaptations are, however, not the only means we find to secure cross-pollination. There are peculiarities connected with what we may call the receptivity of the pistil for any particular pollen. Of these the most generally occurring is *dichogamy*, or the maturing of the microsporophylls and the macrosporophylls at different times. Two varieties of

this condition are met with; in the first, known as *protandry*, the stamens with their pollen are mature while the stigma is still too little developed to be pollinated. Examples may be found in the Gentianaceæ, Onagraceæ, Campanulaceæ, Compositæ, &c. In Parnassia the receptive surface of the stigma is not even formed until the anthers have discharged their pollen. The second condition is called *proterogyny*, and is the converse of the first, the stigma withering before the pollen is mature. This condition occurs in both anemophilous and entomophilous flowers; certain of the plantains (*Plantago*) and some grasses (*Anthoxanthum*, &c.) show it in the former group, as does *Scrophularia* among the latter.

Something corresponding to dichogamy is found among the Ferns, where the antheridia and archegonia on a prothallium do not mature simultaneously. Cross-fertilisation must consequently be the only form possible. The same peculiarity may be observed among the Mosses.

Another means often observed to secure cross-pollination is *diclinism*, or the production of the stamens and carpels in different flowers. Diclinous plants may be *monœcious* where the staminate and pistillate flowers are on the same plant, *diœcious* where they are on different plants, or *polygamous* where a plant bears hermaphrodite flowers as well as either staminate or pistillate ones.

The same terms 'monœcious' and 'diœcious' are often applied to the Cryptogams, when their sexual organs are upon the same or different plants. They then refer, of course, to the gametophyte and not the sporophyte phase as in the cases just quoted.

Some flowers show a peculiarity in form, which is sometimes an adaptation favouring cross-pollination. The plants possess flowers of two kinds, which are specially related to each other. The most familiar instance in our own flora is the common Primrose, which has five stamens and a club-shaped stigma. In some flowers the stigma is placed just in the throat of the corolla and the stamens some little way down its tube. In the remaining flowers the positions are reversed. We have here an adaptation to the visiting insect, for when it touches the stamens of a short-styled form it covers with pollen the part which will come in contact with the stigma of the next long-styled flower it alights upon. The best seeds are produced when each stigma is supplied with pollen from stamens occupying a corresponding position.

This arrangement is generally spoken of as *dimorphism*, of which, however, it is only one form. *Lythrum Salicaria* is trimorphic, having two sets of stamens of different lengths and a style which differs from both. There are three modes of arrangement of these organs, and, as in the Primrose, the most serviceable pollination is that which takes place when pollen from a stamen of a certain length is applied to a stigma of the same length.

Other arrangements are physiological rather than structural. Of these the strangest is what is called *prepotency*. When a stigma of a flower exhibiting this property is pollinated by pollen from its own stamens and at the same time by pollen taken from another flower, the latter is always the originator of the gamete by which fertilisation is effected. Some flowers show *self-sterility*, that is, they are never fertilised if only pollinated by pollen from their own stamens; in some few cases their own pollen acts as a poison to them.

Though cross-pollination is thus seen to be most advantageous, it is not universal. Self-pollination occurs in many plants; indeed, in some, special means have been developed to secure it in case cross-pollination fails to be effected. Only one of these need here be alluded to; this is *cleistogamy*, or the production of special flowers which do not open, in addition to the normal ones. The pollen grains put out their pollen tubes in the unopened flowers, sometimes not even escaping from the sporangia. The tubes grow towards the stigmas, and, penetrating them, reach the ovules as in the case of the normal flower, fertilisation resulting in the same way.

Though cross-fertilisation is seen to be most advantageous, it is only possible within certain limits. For a new individual to be produced, the sexual cells taking part in the process must have a certain degree of relationship; thus the antherozoid of a moss cannot fertilise the oosphere of a fern. The most favourable degree of relationship is that the two gametes shall be produced by different plants of the same species. Such a union results in greater numbers and greater vigour in the offspring. Plants, however, not so closely related, may produce offspring; thus we may have the union of gametes of plants standing to each other in the relation of varieties of the same species, or very frequently of distinct species belonging to the same genus, or even of species of different genera. Such fertilisation is known as *hybridisation.*

Hybrids generally exhibit peculiarities of form and structure

intermediate between those of their parents; they are generally fertile with either of the parent species, but not usually so with another hybrid, or to a much less extent. When crossed with one of the parent forms the offspring tend to revert to that form.

The result both of pollination and of fertilisation is generally to stimulate the parts concerned to increased growth. In some Orchids the ovules are not formed in the ovary until the stigma is pollinated and seem to arise in consequence of that process. The stimulus of fertilisation is still more marked. In the Mosses its result is to cause not only development of the sporophyte from the oosphere but a considerable additional growth of the archegonium, forming the calyptra. The same thing may be noted in those Rhodophyceæ where a bulky cystocarp is produced. The stimulus is, however, most easily observed in the Angiosperms, where not only is the oosphere excited to growth, forming the embryo, but the definitive nucleus of the embryo sac gives rise to the endosperm, and the pistil or collection of macrosporophylls and sometimes other parts of the flower undergo remarkable development, forming the fruit.

We have noticed that the asexual reproductive cell, whether spore or gonidium, is generally found to remain in a state of quiescence for some time after its formation. The same thing is seen in the case of the zygote. In the Thallophytes this resting period is sometimes a long one; in the higher Cryptogams it is not so noticeable, and in the Phanerogams, where the zygote is always developed inside the sporangium, it usually proceeds to active growth at once. In the latter plants, however, a resting period takes place later, after the seed is fully formed. The development of the young sporophyte in fact takes place in two stages, the one ending with what may be called the maturity of the seed, the other beginning with the process of germination. Seeds when detached from the parent plant preserve their vitality for a variable length of time, sometimes even for years, and are capable of germinating freely when exposed to favourable conditions.

The germination of the dicotyledonous seed occurs in one of two methods. In the first of these the cotyledons are thick and fleshy and remain under ground. As the seed absorbs water and swells, the radicle makes its way out through the micropyle, the testa bursts, and the plumule makes its way upwards, the epicotyl, or part between the cotyledons and the first leaves,

circumnutating and emerging in the form of an arch, owing to the greater growth of one side. After reaching the air the region of greatest growth changes to the opposite side and the epicotyl straightens itself. During this time it subsists upon the nourishment stored in the cotyledons. This is called *hypogean* germination. In the other method, that of the so-called *epigean* germination, the cotyledons rise above the ground and become green, the hypocotyl behaving as did the epicotyl in the first case. These are generally, though not always, albuminous seeds, and the nutritive matter is stored outside the embryo. In both cases the root makes its way into the soil by virtue of its geotropism and apheliotropism, aided by the movement of circumnutation, and by the adhesion of the root-hairs to particles of the soil. In Monocotyledons the upper part of the single cotyledon generally remains in the seed and absorbs the nutriment from the endosperm, while its base elongates and thrusts the young plant downwards.

Sometimes the usual alternation of sexual and asexual reproduction in the higher plants is interfered with by the substitution of the vegetative method for one of them. In the phenomenon of *apospory* noticeable in some Ferns we have small prothallia developed on the back of the leaves in the place of spores. This is a case of the production of a bud instead of an asexual cell. Conversely, among the same group of plants, the sporophyte sometimes arises as a bud or vegetative outgrowth upon the prothallium, a phenomenon known as *apogamy*.

There is another kind of apogamy known which is generally termed *parthenogenesis*. This occurs among the Fungi, where, as in Saprolegnia, oospheres are formed in oogonia, which do not become fertilised and yet have the power of growing out into new plants. The formation of *azygospores*, described as occurring in Mucor and other plants, is another case of the same phenomenon. This parthenogenesis differs from the phenomenon described as occurring in *Cœlebogyne*, where nevertheless an embryo is produced without pollination. This we have seen to be due to a vegetative budding of the cells of the nucellus of the ovule, the buds growing into the macrospore and there developing into embryos.

GLOSSARY AND GENERAL INDEX

TO VOL. II.

Absence of pericycle, 130, 140, 143, 154
Absorption by root-hairs, 416, 436
— of gases, 438
— — nitrogen by Leguminosæ, 437; by pitcher plants, 440, 453
Accrescent. A term applied to the calyx, when it continues to grow after pollination of the pistil
Achlamydeous. Having neither calyx nor corolla
Acropetal succession. The regular development of leaves or branches in such order that the youngest is always nearest to the apex of the axis which bears them
Actinomorphic flowers. Flowers which can be divided into two precisely similar halves by every possible vertical section
Acyclic flowers. Those in which the leaves of the flower are arranged spirally on the axis instead of being in whorls
Adhesion. The condition of union to, or freedom from, one another of the separate whorls of the floral leaves
Adventitious. Arising irregularly, or not in acropetal succession. Applied to certain branches of stem or root
Æcidiospores, 89
Æcidium, 74, 87
Æstivation. The mode in which the leaves of the perianth are arranged in the flower-bud
After-effect, 511
Aggregation, 498, 505
Aleurone grains, 451
Alliances, 6
Alternation of generations (*antithetical*). A regular alternation of gametophyte and sporophyte in the life cycle of a plant, 514
— — — (*homologous*). An irregular succession of gametophytes, some of which produce sexual cells while the remainder only develop gonidia, 31, 515
Amentaceous. Having its flowers arranged in catkins
Amides, 444, 467
Amœboid movements. The creeping movements of masses of naked protoplasm, 67, 76
Amphigastria, 110
Amphitropous. Semi-anatropous
Anabolism, 433
Anatropous ovule. One whose nucellus remains straight but which becomes inverted during development, owing to the greater growth of one side
Andrœcium. The collection of stamens in a flower
Androphore. The column or tube formed by the coalescence of the filaments of the stamens when the latter are monadelphous
Androspore, 61
Anemophilous, 519
Annulus, 120, 134, 150
Antheridial cell in Gymnosperms, 175
Antheridiophore. Any special part of the gametophyte on which antheridia arise
Antheridium. The organ in which the male gametes, usually antherozoids, are developed
Antherozoids or spermatozoids. Male ciliated gametes, with no cell-wall
Anthesis. The period at which the flower-bud opens.
Anticlinal. A term applied to those cell-walls which are formed at right angles to the surface of the growing point
Antipodal cells, 182
Antitropous. Inverted. A term applied to the embryo
Apheliotropism, 493
Apocarpous. A term applied to the pistil when its constituent carpels are not coherent together
Apogamy, 126, 523
Apogeotropism, 494
Apophysis, 119
Apospory, 120, 126, 523
Apostrophe, 487
Apothecium, 84
Aquatic phanerogams, 478

Archegoniophore. Any special part of the gametophyte on which archegonia arise
Archesporium. The cell or cells which by division give rise to the mother cells of the spores
Archicarp, 70, 82
Aril. A third integument which grows completely or partially over the seed springing from its base
Ascending sap, 416
Ascidia. The pitchers of such plants as Sarracenia, Nepenthes, &c.
Ascocarp, 83
Ascogonium, 83
Ascospores, 87
Ascus, 82
Asexual reproduction, 513
Ash of plants, 436
Astely=schizostely
Asymmetrical flowers. Those which cannot be divided into similar halves by any vertical section
Autœcious, 90
Auxiliary cells, 51
Auxospores, 41
Axil. The angle formed by the junction of leaf and stem
Azygospores, 55, 78

Basidia, 90
Basidiospores or basidiogonidia, 92
Bicollateral bundles. Those which have a strand of bast both before and behind the strand of wood
Bye-products of metabolism, 461, 464

Caducous sepals. Those which become detached from the flower when the flower-bud opens
Callus. The material which is developed upon the surface of sieve-plates. Also applied to the tissue which grows over and covers wounds made in a stem or root
Campylotropous ovule. One whose nucellus is curved so that the micropyle is placed close to the hilum
Capillitium, 77
Capitulum (of Chara), 63
Carpogonium, 82
Carpophore. The part of the axis of the flower which is between or above the carpels, and to which they are attached
Carposporangia, 51
Caruncles=strophioles
Catabolism, 433, 460
Caudicles. The stalks of the pollinia in the Orchidaceæ
Cell-wall, composition of, 421
Chalaza. The point at which the vascular bundle reaches the ovule
Chemiotaxis, 499, 500
Chlamydospore, 78
Chlorophyll, 440, 462
Chloroplasts. The chlorophyll corpuscles, 434
Chlorotic plants, 463
Chorisis. An increase in the number of the parts of a floral whorl due to the division or splitting of its primary members
Chromatophores=chromoplasts
Chromoplasts. Small protoplasmic bodies found in certain cells and containing colours other than green
Cilia. Vibratile filaments of protoplasm found on zoospores, gametes, &c. Also applied to the inner row of teeth of the peristome of mosses
Ciliary motion, 507
Circumnutation, 476
Cirrhus. A tendril
Cladode. A branch which in shape resembles a leaf
Cleistogamy, 521
Cleistothecium, 83
Cœnobium, 54
Cœnocyte. A plant body in which the constituent protoplasts are not separated from each other by cell-walls. Usually a common cell-wall invests the whole
Cohesion. The condition of union or freedom of the separate members of the whorls of the floral leaves
Cohorts, 6
Collenchyma. A parenchymatous or prosenchymatous tissue, the cells of which are thickened at their angles
Columella, 77, 118
Comose. A term applied to seeds which bear a tuft of hairs
Conceptacles. Depressions in the surface of the thallus of certain algæ in which the reproductive organs are borne, 43
Conjugation. The fusion of two similar gametes, 517
Coriaceous. Leathery—applied to leaves
Cormophyte. A plant which possesses stem and leaf
Corona. A cup-shaped body formed by the lateral union of scales borne upon the perianth leaves at the junction of claw and limb, as in the Daffodil
Cryptostomata, 45
Crystalloids, 451, 452
Cupule. The involucre of the female flower of the Oak, Hazel, &c.
Cushion. The central thick region of the prothallus of the fern, 136, 137
Cystocarp, 32, 51
Cytase, 455, 457

Deduplication. A doubling of the number of parts of a floral whorl
Definitive nucleus, 182
Diageotropism, 494
Diaheliotropism, 493
Dialystely. A variety of polystely in

being separated by conjunctive or ground tissue
Gamopetalous. Having the petals cohering laterally (similarly gamosepalous)
Gamostelic. The condition when the steles of a polystelic stem are arranged in a ring and more or less completely fused together laterally
Gemmæ. Vegetative reproductive structures found among the Thallophyta and Bryophyta, 38, 65, 104, 110, 117
Genera, 4
Genetic spiral. The line which may be drawn round a stem with alternate phyllotaxis, passing in regular succession through the bases of the leaves
Geotropism, 494
Gills (of Mushroom), 91
Globoids, 451
Globule. The antheridium of Chara
Glochidia, 147
Glucase, 455, 456
Glucosides, 462, 458
Gonidangia. The structures in which gonidia are produced
Gonidia. The asexual reproductive cells produced upon gametophytes. They are sometimes also called spores
Gonidiophore, 71
Gonidiophylls. Leaves of the gametophyte which bear gonidangia
Gonimoblasts, 51
Growing points, 36
Growth, 470
— effect of light upon, 488
— grand period of, 474
Gynandrous. A term used to indicate that the filament or filaments of the andrœcium of a flower are united with the upper part of the pistil, forming a central column
Gynobasic style. One which springs from the base of the carpel instead of its apex
Gynœcium. The pistil, or collection of carpels in a flower
Gynophore. The part of the axis of the flower between the insertions of the stamens and ovary

Haptera. The organs of attachment of certain Algæ, 36
Haustoria. The outgrowths through which many parasites absorb nourishment from their host plants. They are generally of the nature of roots
Heliotropism, 493
Hemicyclic flowers. Those in which the perianth leaves are arranged in whorls and the sporophylls in spirals
Hermaphrodite. A term applied to flowers possessing both stamens and carpels, also to gametophytes producing reproductive cells of both sexes
Heterocysts, 39
Heterodromous. A term used to indicate that the genetic spiral of the leaves of a stem turns in a different direction from those of the branches
Heterœcious. A term applied to certain fungi, which in different phases of their life infest two different plants, 90
Heterogamous. Having differentiated male and female gametes
Heteromerous, 96
Heterospory. The peculiarity of producing macrospores and microspores, possessed by many of the Pteridophyta and all the Phanerogamia, 514
Homodromous. A term used to indicate that the genetic spiral of the leaves turns in the same direction in the stem and its branches
Homoiomerous, 96
Homosporous = isosporous. Possessing only one kind of spore
Homotropous. Erect. A term applied to the embryo
Hormogonia. Vegetative reproductive bodies of the Cyanophyceæ, 39
Humus, 416
Hybridisation, 521
Hydrophilous, 519
Hydrotropism, 499
Hymenial layer, 84, 91
Hyphæ. The thread-like cells or filaments of the fungi
Hypocotyl. That part of the axis of a seedling which lies between the base of the radicle and the insertion of the cotyledons
Hypoderma. The region immediately underlying the epidermis
Hypogynous. Springing from the axis of the flower below the ovary. Applied to petals and stamens
Hyponasty, 475
Hypophysis, 185
Hypsophyll. Bract

Indusium. The membrane covering a sorus or collection of sporangia, 133, 145. Also applied to the cup-shaped expansion of the upper part of the style in the *Goodeniaceæ*, 374
Integuments, 171
Inulase, 455, 456
Invertase, 455, 456
Involucre. A whorl or collection of bracts at the base of a flower or an inflorescence
Irritability, 484
Iso-bilateral. A term applied to leaves whose upper and lower halves have the same structure
Isogamous. Having gametes which are not differentiated into male and female
Isomerous flowers. Those which have the same number of parts in each of the floral whorls
Isosporous. A term applied to plants which have spores of only one kind

Isostemonous. Having the same number of stamens as of sepals and petals

Karyokinesis. The process of indirect division of the nucleus
Klinostat, 495

Latent period, 511
Leptosporangiate. A term applied to those plants whose sporangia arise each from a single epidermal cell, 122
Leucoplasts. The plastids which form starch grains in parts of plants not exposed to light, 449
Ligule of grasses, 216
— — Lycopodinæ, 160
Localisation of sensitiveness, 502, 504
Loculicidal. Splitting down the dorsal sutures. Applied to the dehiscence of capsular fruits
Lodicules, 217
Lysigenous spaces. Such as are produced by the absorption or disintegration of cells

Macrosporangia-development in Phanerogams, 171
Macrospores. The larger spores borne by heterosporous plants
Manubrium, 63
Marcescent. A term applied to the calyx or corolla when it withers after pollination but does not become detached
Massula, 147
Megaspores=macrospores
Meiostemonous. Having fewer stamens than petals
Merismatic. Capable of division. A term applied to groups or bands of cells which undergo continuous multiplication
Meristeles. The branches of the stele which enter the leaves
Meristem. A collection of cells which increases continuously by cell-division
Metabolism. The chemical changes associated with the life of protoplasm, 433
Micropyle. The aperture left at the apex of the ovule in consequence of the integuments not completely enclosing it
Microsporangia-development in Phanerogams, 169
Microspores. The smaller spores borne by heterosporous plants
Monadelphous. A term used to indicate that the stamens of a flower are united by the bases of their filaments
Monandrous. Having only one stamen
Monochlamydeous. Having only one whorl of perianth leaves
Monœcious. A term applied to those Phanerogams which produce staminate and pistillate flowers upon the same plant. Also used to indicate gametophytes which bear both antheridia and archegonia, 520
Monopodial. A term applied to such branch systems as have a main axis produced by the continuous activity of a single growing point
Monostely. The condition in which the centre of the axis of the plant is occupied by a single stele which is continuous with the plerome
Mycelium. The delicate network of thread-like cells or cœnocytes which form the body of a fungus
Myrosin, 456

Natural Orders, 5
Nitrification, 437
Nucellus. The body of the ovule, 171
Nucleoplasm. The substance of which the nucleus is composed
Nutation, 476
Nyctitropic movements, 489

Obdiplostemonous. A term used to indicate an andrœcium, which consists of two whorls of stamens, those of the outer whorl being opposite to the petals
Occurrence of *Monochlamydeous* flowers in Polypetalæ and Gamopetalæ, 261
Ochreæ. The stipules of the Polygonaceæ
Oidium, 73
Ooblastema filament, 51
Oogamous. Producing gametes of two kinds, one male, the other female
Oogonium. The organ in which the female gametes of the Thallophytes are developed
Oosphere. The female gamete before fertilisation
Oospore. The body formed by the fertilisation of an oosphere. Often called a zygote
Operculum. The lid of the capsule of a moss
Orthostichies. The vertical ranks of the leaves upon a stem
Orthotropous. A term applied to ovules which grow vertically from the placenta, so that the chalaza and the hilum are close together at the base, and the micropyle is at the opposite end or apex
Osmosis, 411
Ostioles, 43

Paleæ. Scarious leaves which form the outer covering of the flowers of grasses; also scales which are found at the bases of the flowers in the capitula of certain Compositæ.
Pappus. The hairy or feathery calyx of the flowers of the Compositæ and allied orders
Paraheliotropism, 486

Paraphyses. Hair-like outgrowths formed among the sexual organs or sporangia of Thallophytes, Bryophytes, and Ferns, 44
Parasites. Plants which live upon other plants or animals by absorbing nutritive materials from their tissues, 482
Paratonic action of light, 488
Parthenogenesis. The development of a new plant from a sexual cell without fertilisation, 523
Pectase, 455, 457
Peloria. A term applied to the condition when flowers which are normally irregular in form become regular
Pepsin, 455, 477
Periblem. The embryonic tissue which gives rise to the cortex of vascular plants
Pericambium. An old name for the pericycle of the root
Perichætium, 107
Periclinal. A term applied to cell-walls which are formed parallel to the surface of the growing point
Pericycle. The circumferential layer of the stele
Peridium, 92
Perigynium, 108
Perinium, 147
Periodicity, 510
Peripherical. A term applied to the embryo when it more or less completely surrounds the endosperm in the seed
Periplasm, 79
Perisperm. The remains of the nucellus of the ovule when it is not all absorbed by the macrospore or embryo sac during the development of the latter, 177
Peristome, 118
Perithecium, 85
Phototaxis, 494
Phototonus, 484
Phragmata. Spurious dissepiments crossing the ovary horizontally, as in *Cassia*
Phycocyanine, 26
Phycoerythrine, 36
Phycophæine, 36
Phycoxanthine, 36
Phyllaries. The bracts forming the involucre of the Compositæ and allied orders
Phyllotaxis. The arrangement of the leaves upon the stem
Pileus, 91
Placenta. The part of the sporophyte on which the sporangia arise
Plasmodium. The body of a Myxomycete, 67, 76
Plerome. The embryonic tissue which gives rise to the stele
Pollination, 518
Pollinia. The masses of pollen produced in the lobes of the anthers of the Orchidaceæ and Asclepiadaceae
Pollinodium, 70, 79
Pollinoid, 50
Polygamous, 520
Polystely. The condition in which the vascular tissue of the axis is arranged in several steles, each containing more than one vascular bundle
Præfloration. The arrangement of the leaves in the flower-bud
Prefoliation. The arrangement of the foliage leaves in the bud
Prepotency, 521
Primordial cells. Cells with no cell-wall
Primordial utricle. The part of the protoplasm of a cell which lines the cell-wall
Procambium. The embryonic tissue that develops into the vascular bundles
Procarpium. The female organ of the Rhodophyceæ and the Ascomycetes
Pro-embryo of Chara, 65
Pro-mycelium, 66, 78
Protandry, 520
Proteids, classification of, 445
Proterogyny, 520
Prothallium, 125
Protobasidium, 88
Protonema. The body produced from the spore of a Bryophyte, on which the gametophyte is developed vegetatively
Protoplasts. The separate aggregations of protoplasm, each of which constitutes the living substance of a cell, 409
Pseudocarp. A fruit into the composition of which other parts than the pistil enter
Pseudopodia, 76, 507
Pycnidia, 85
Pyrenoids, 37

Quincuncial. A term applied to the æstivation of such flowers as have five leaves in a whorl, arranged so that two are overlapped on both sides by their neighbours, two are not overlapped at all, and the fifth is overlapped on one side only

Races, 3
Ramenta, 129
Raphe. The part of the funiculus which is adherent to the side of an anatropous or amphitropous ovule
Receptacle. The dilated apex of a peduncle on which several flowers are borne, as in a capitulum. Sometimes applied to the axis of the flower within or above the calyx
Rectipetality, 478
Rejuvenescence. A process in which the protoplasm of a cell withdraws from the cell-wall, rounds itself off in the cavity, and secretes a new cell-wall for itself. It is one of the processes of the formation of new cells
Rennet, 456
Replum. The spurious longitudinal dissepiment of the siliqua and silicula. It is formed by an outgrowth from the two placentas, and not by the edges of the carpellary leaves, 274

Retinacula. Glandular bodies at the bases of the pollinia in some Orchids
Rhamnase, 456
Rhizophores, 161
Rhythm, 509
— artificial, 511
Root-hairs, action of, 417
Root-parasitism, 440
Root-pressure, 418, 425
Rostellum. A peculiar projection into the flower of some Orchids. It is formed by a modification of one of the stigmas

Saprophytes. Plants which grow on decaying organic matter, from which they derive their nourishment, 66
Sarcocarp. The fleshy middle layer of the drupe
Schizostely. A condition in which an axis has several steles, each of which is composed of only one vascular bundle, 151
Sclerotia, 73, 86
Secondary growth in thickness in Thallophytes, 31, 35, 36, 43, 46
— in Isoëtes, 123, 164, 165
— — Ferns, 123, 140
Secretion, 461
Seed, structure of, 177
Self-sterility, 521
Septicidal. Splitting down the ventral sutures. Applied to the dehiscence of capsular fruits
Septifragal. A term applied to the mode of dehiscence of capsules in which the pericarp becomes detached and leaves the seeds adhering to a central column formed by the axile placentas
Series, 6
Sexual reproduction, 514
Shields, 63
Sleep movements, 489
Soredia, 97
Sorus. A collection of sporangia
Species, 2
— derivation of names of, 8
Spermatium, 50, 70, 83
Spermatozoid = antherozoid
Spermogonium, 70, 83
Sphacelia, 86
Sporidium, 88
Sporophore. The part of the sporophyte which bears the sporophylls. Usually applied to the inflorescence of Phanerogams
Sporophylls. Leaves which bear sporangia
Sporophyte. The phase of the plant which is characterised by the production of spores, and cannot produce sexual cells
Sports, 3
Starch grains, formation of, 449
Stele. A strand of tissue in which are embedded one or more vascular bundles, and which is surrounded by an endodermis
Stereome. The supporting tissue of the plant. It includes the vascular bundles and the sclerenchyma and collenchyma
Sterigma, 70, 83
Stipes, 91
Stipules. Branches of the hypopodium or leaf-base
Stoma of Marchantia, 105
Stomata, action of, 429
Stomium. The cells of the annulus of the fern which rupture to allow of the escape of the spores, 134
Stromata, 87
Strophioles. Small protuberances growing from various regions of the testa of the seed. They are never developed before fertilisation
Stylogonidia, 71
Stylopodium. The epigynous disc found in the flowers of the Umbelliferæ
Sub-classes, 6
Suspensor, 124, 155, 176, 184
Symbiosis. A term employed to denote the living together of two plants to their mutual advantage. The best example is afforded by the Lichens, 110, 144
Synangium, 122, 142, 158
Syncarpous. Having the carpels cohering together to form a compound ovary
Synergidæ, 183
Syngenesious. A term applied to stamens whose anthers are united together, while their filaments are free
Systems of classification, 16, 17

Tapetum. A nutritive layer usually surrounding the sporogenous tissue of the archesporium
Teleutospore or teleutogonidium, 71, 83
Tendrils, 496
Tensions in plants, 476
Tetradynamous. A term applied to the arrangement of the stamens in the Cruciferæ
Tetraspores or Tetragonidia. The asexual reproductive cells of the Rhodophyceæ
Thallose liverworts, 104
Thallus. A plant body showing no differentiation into stem, leaf and root
Thyloses. A tissue often found in the interior of vessels or tracheïds. It is formed by a cell of the adjacent tissue boring its way into the vessel through a pit and then multiplying by cell-division
Trama, 91
Transfusion tissue. A tissue surrounding the vascular bundles in the meristeles of the leaves of the Coniferæ
Transpiration, 419, 425, 427
— conditions of, 429
— importance of, 430
— current, 442

INDEX OF PLANTS

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